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Bengtsson et al.

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(45) **Date of Patent: Jul. 4, 2006**

(54) **IQ MODULATION SYSTEMS AND METHODS THAT USE SEPARATE PHASE AND AMPLITUDE SIGNAL PATHS AND PERFORM MODULATION WITHIN A PHASE LOCKED LOOP**

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(73) Assignee: **Telefonaktiebolaget L.M. Ericsson**, Stockholm (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 923 days.

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(22) Filed: **Dec. 22, 2000**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 09/703,037, filed on Oct. 31, 2000, now Pat. No. 6,975,686.

(51) **Int. Cl.**
H04L 27/36 (2006.01)

(52) **U.S. Cl.** **375/298**; 332/127

(58) **Field of Classification Search** 375/298, 375/300, 301, 302, 322, 327, 317, 296, 371, 375/373, 375, 376, 269, 279, 297, 258, 306, 375/345; 332/108, 119, 120, 123, 125, 126, 332/127, 128, 145, 159–160, 162; 455/138, 455/139, 137, 110, 114.3, 126, 127.1, 127.2
See application file for complete search history.

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Primary Examiner—Khanh Tran
(74) *Attorney, Agent, or Firm*—Myers Bigel Sibley & Sajovec

(57) **ABSTRACT**

A digital signal processor generates in-phase, quadrature-phase and amplitude signals from a baseband signal. A modulator modulates the in-phase and quadrature-phase signals to produce a modulated signal. A phase locked loop is responsive to the modulated signal. The phase locked loop includes a controlled oscillator having a controlled oscillator input. An amplifier includes a signal input, amplitude control input and an output. The signal input is responsive to the controlled oscillator output and the amplitude control input is responsive to the amplitude signal. The phase locked loop that is responsive to the modulated signal includes a controlled oscillator output and a feedback loop between the controlled oscillator input and the controlled oscillator output. The feedback loop includes a mixer that is responsive to a local oscillator. The modulator may be placed in the phase locked loop. In particular, the modulator may be placed in the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input.

17 Claims, 18 Drawing Sheets

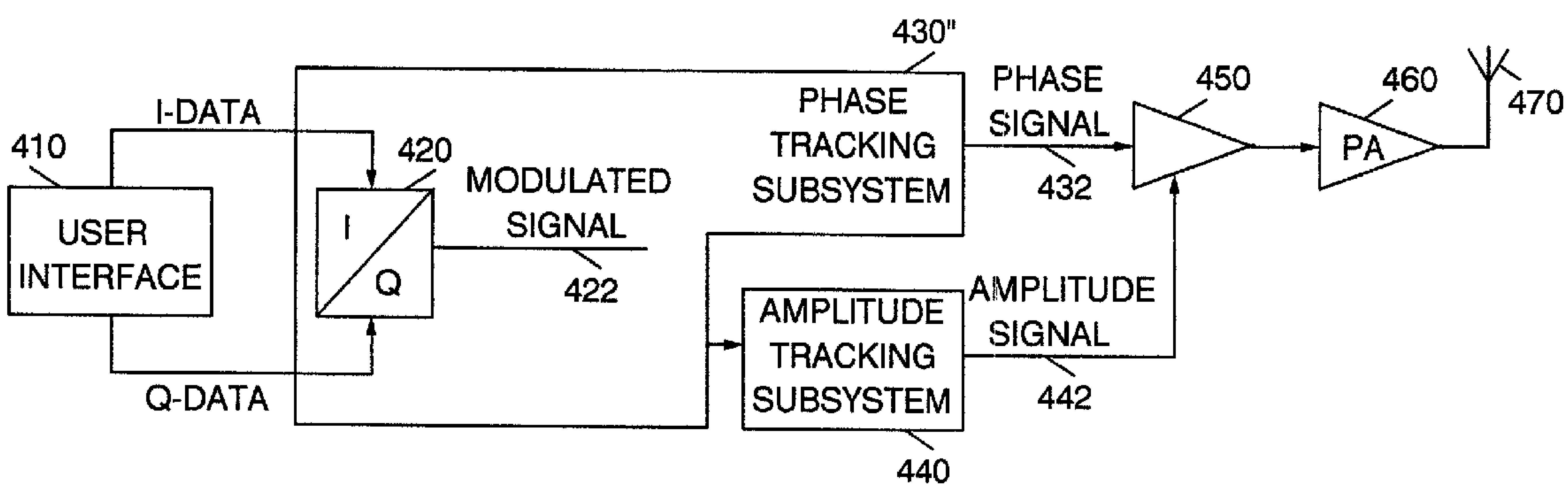

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FIG. 1
PRIOR ART

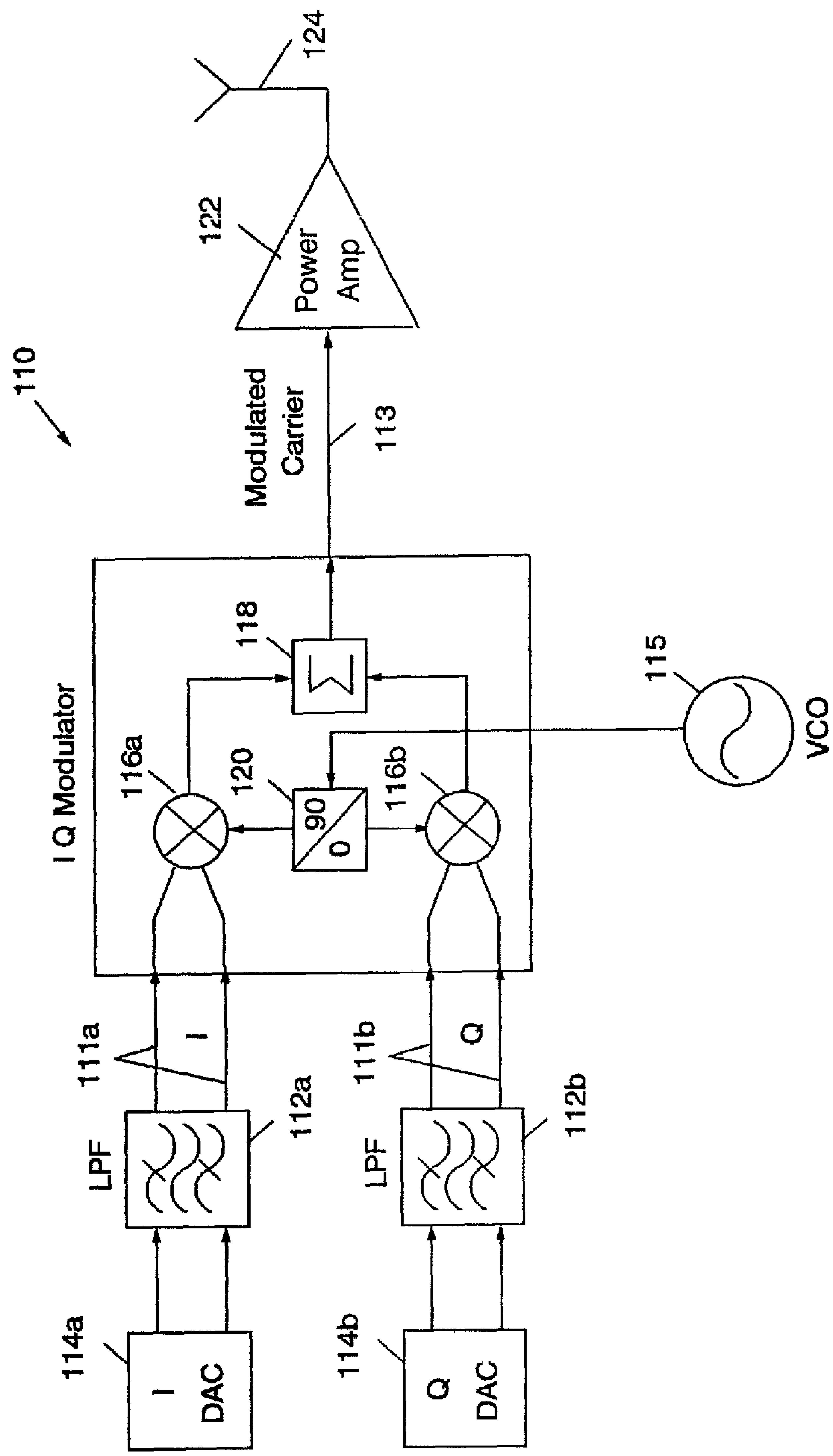


FIG. 2
PRIOR ART

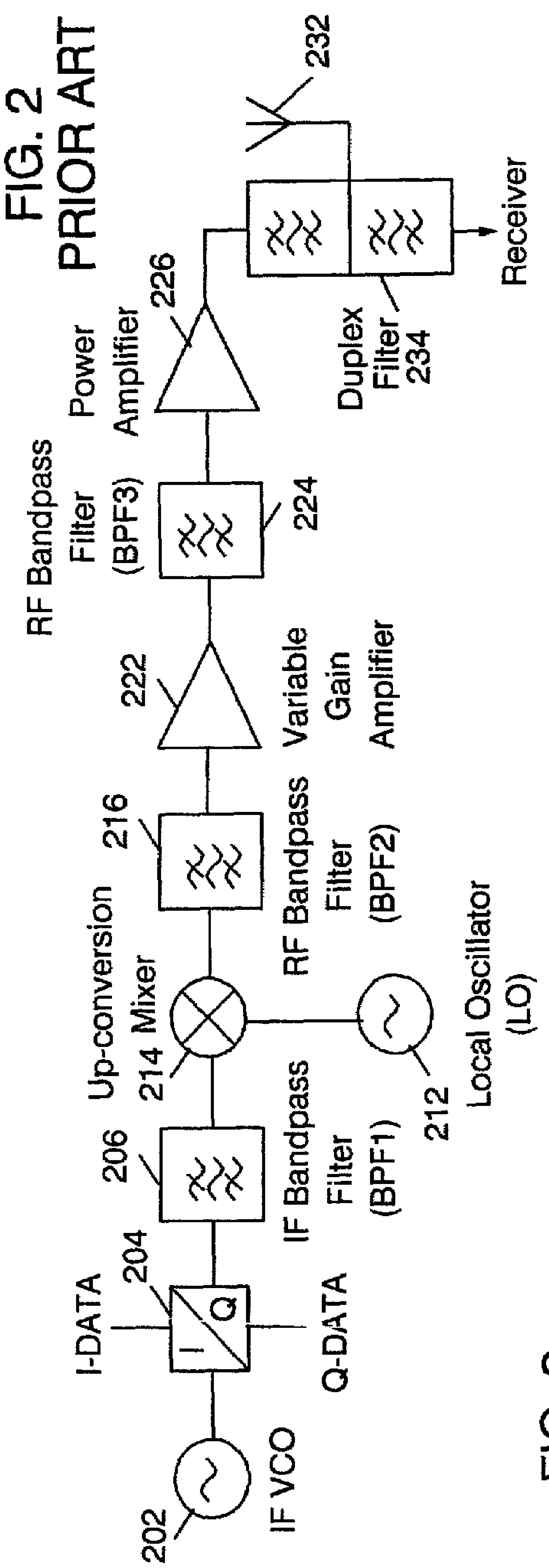


FIG. 3
PRIOR ART

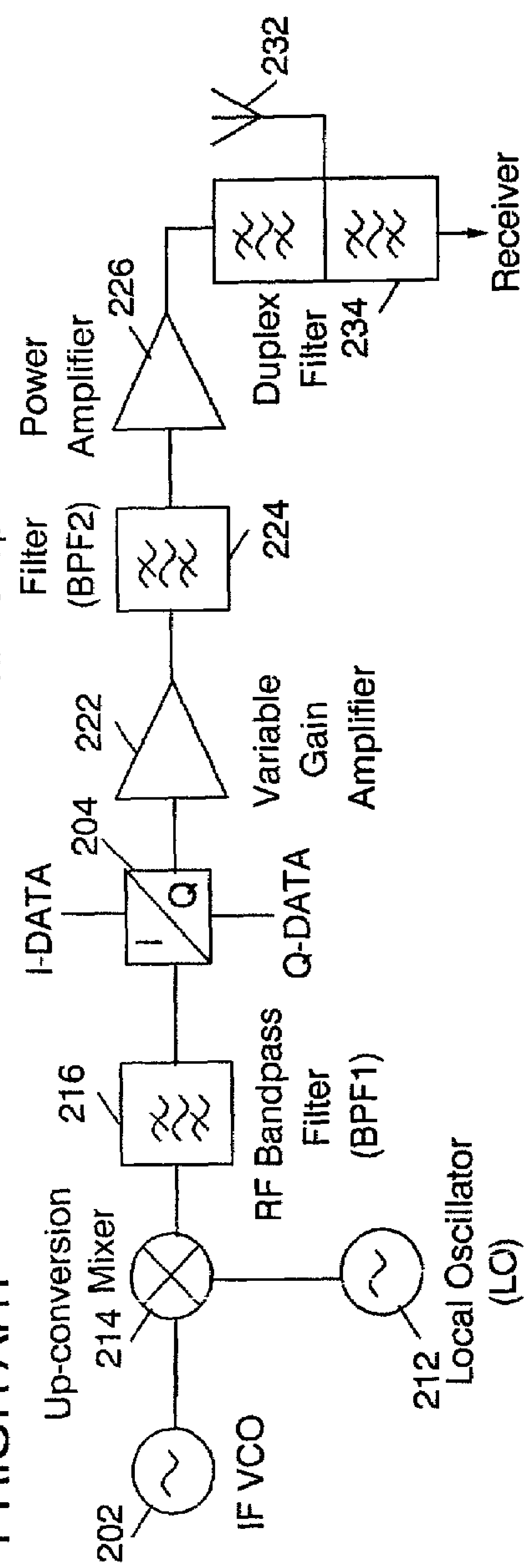


FIG. 4

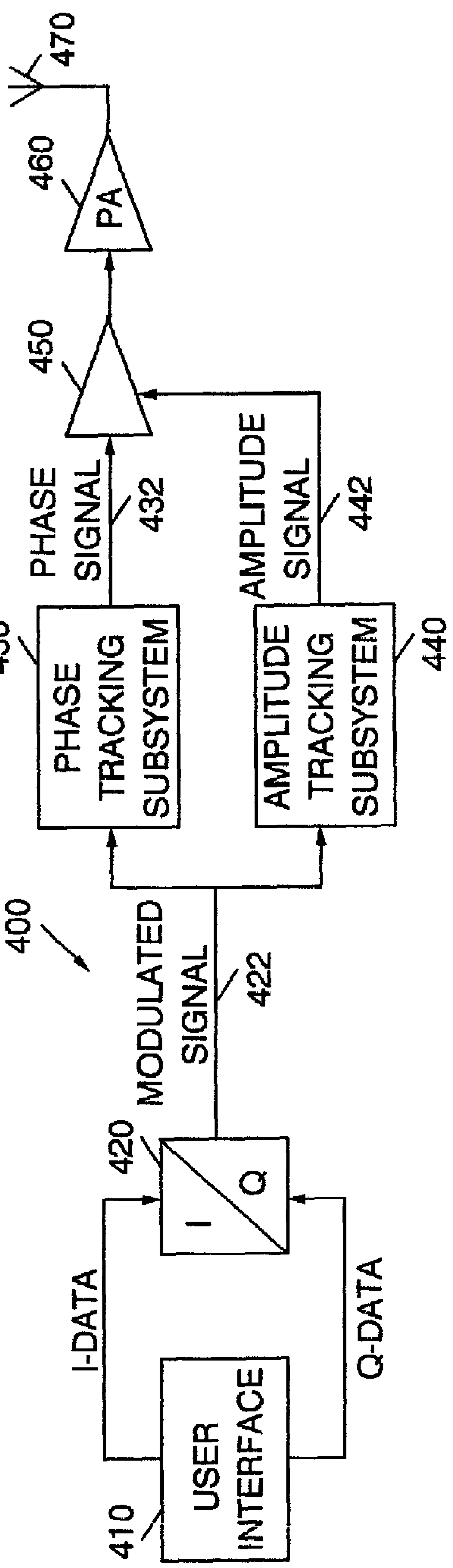
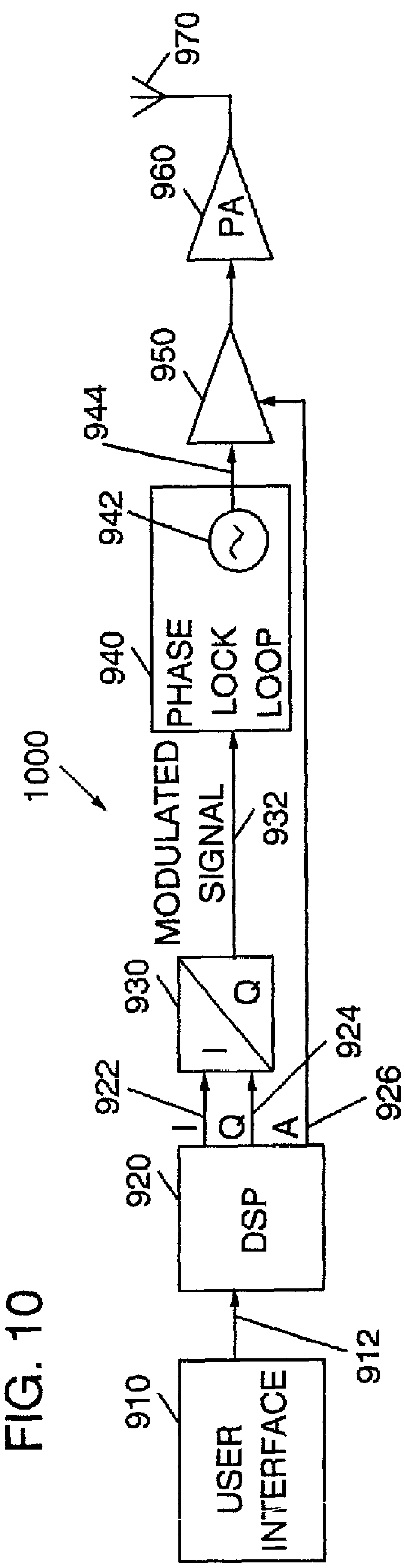

400
410
USER INTERFACE
I-DATA
Q-DATA
420
I
Q
MODULATED SIGNAL
422
430
PHASE TRACKING SUBSYSTEM
440
AMPLITUDE TRACKING SUBSYSTEM
PHASE SIGNAL
432
AMPLITUDE SIGNAL
442
450
460
PA
470

FIG. 10


1000
910
USER INTERFACE
912
920
DSP
922
924
926
I
Q
A
930
I
Q
MODULATED SIGNAL
932
940
PHASE LOCK LOOP
942
944
950
960
PA
970

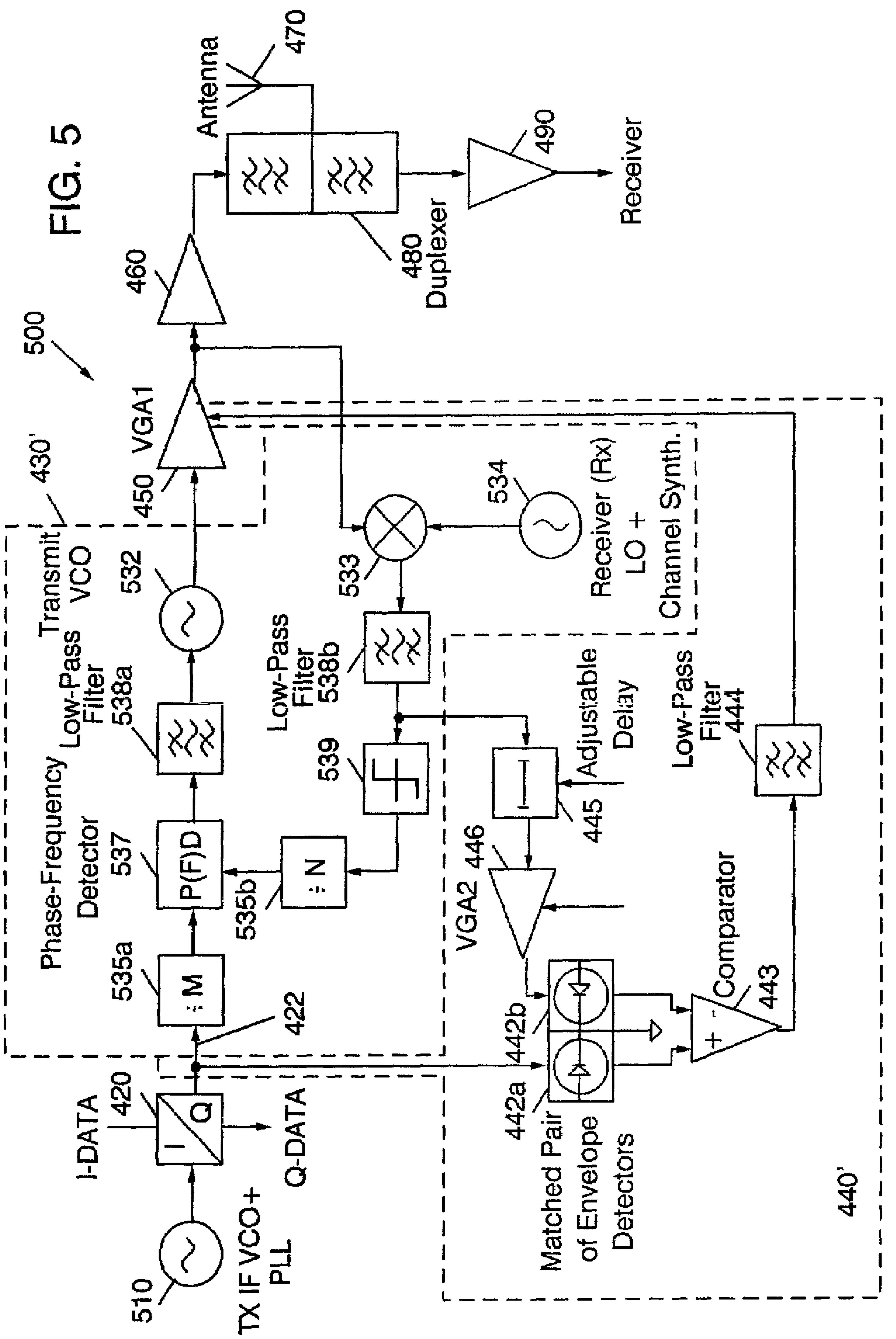

500
Antenna
470
460
480
Duplexer
490
Receiver
430'
450 VGA1
Transmit VCO
532
Low-Pass Filter
538a
Phase-Frequency Detector
537
P(F)D
535a
÷ M
535b
÷ N
422
420
I-DATA
Q-DATA
I
Q
510
TX IF VCO+ PLL
533
534
Receiver (Rx) LO + Channel Synth.
Low-Pass Filter
538b
539
Adjustable Delay
445
Low-Pass Filter
444
VGA2 446
Comparator
443
+
-
442b
442a
Matched Pair of Envelope Detectors
440'

FIG. 5

FIG. 6

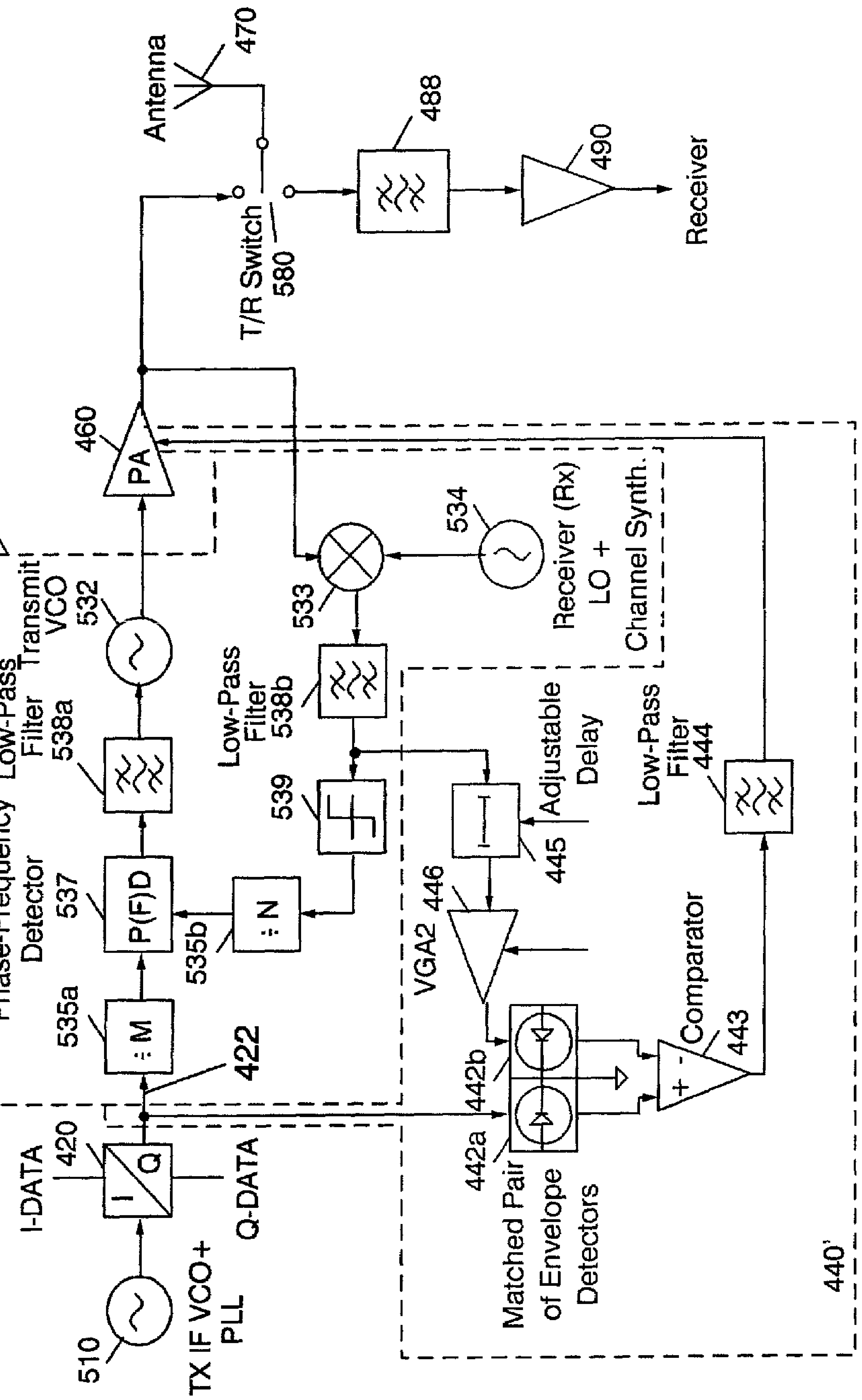

Antenna
470
488
490
Receiver
T/R Switch
580
460
PA
430'
Transmit VCO
532
534
Receiver (Rx) LO + Channel Synth.
533
Low-Pass Filter
538a
Low-Pass Filter
538b
Phase-Frequency Detector
537
P(F)D
539
Adjustable Delay
Low-Pass Filter
444
535a
÷ M
535b
÷ N
445
446
VGA2
Comparator
443
422
420
I-DATA
I
Q
Q-DATA
442a
442b
Matched Pair of Envelope Detectors
510
TX IF VCO+ PLL
440'

FIG. 7

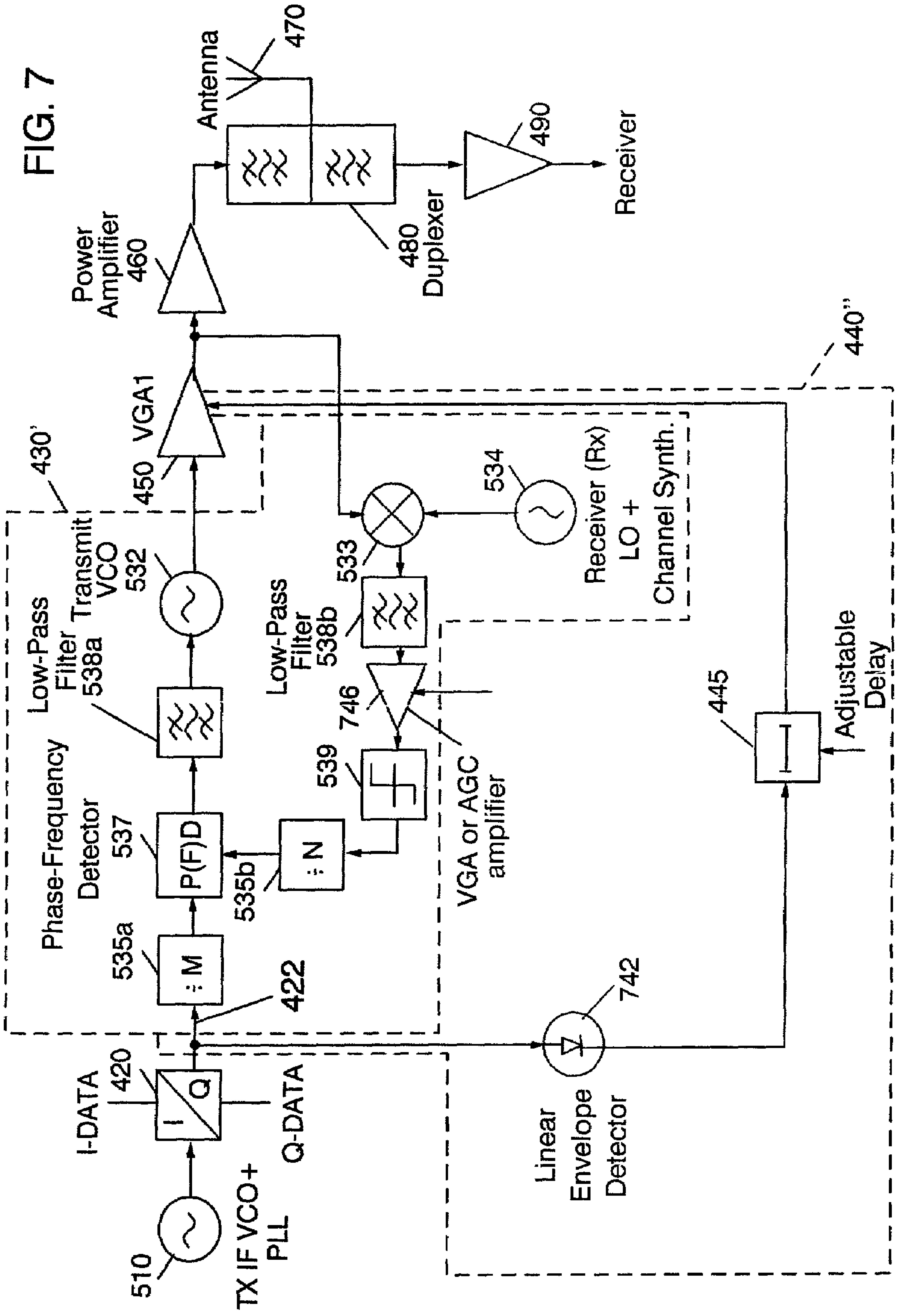
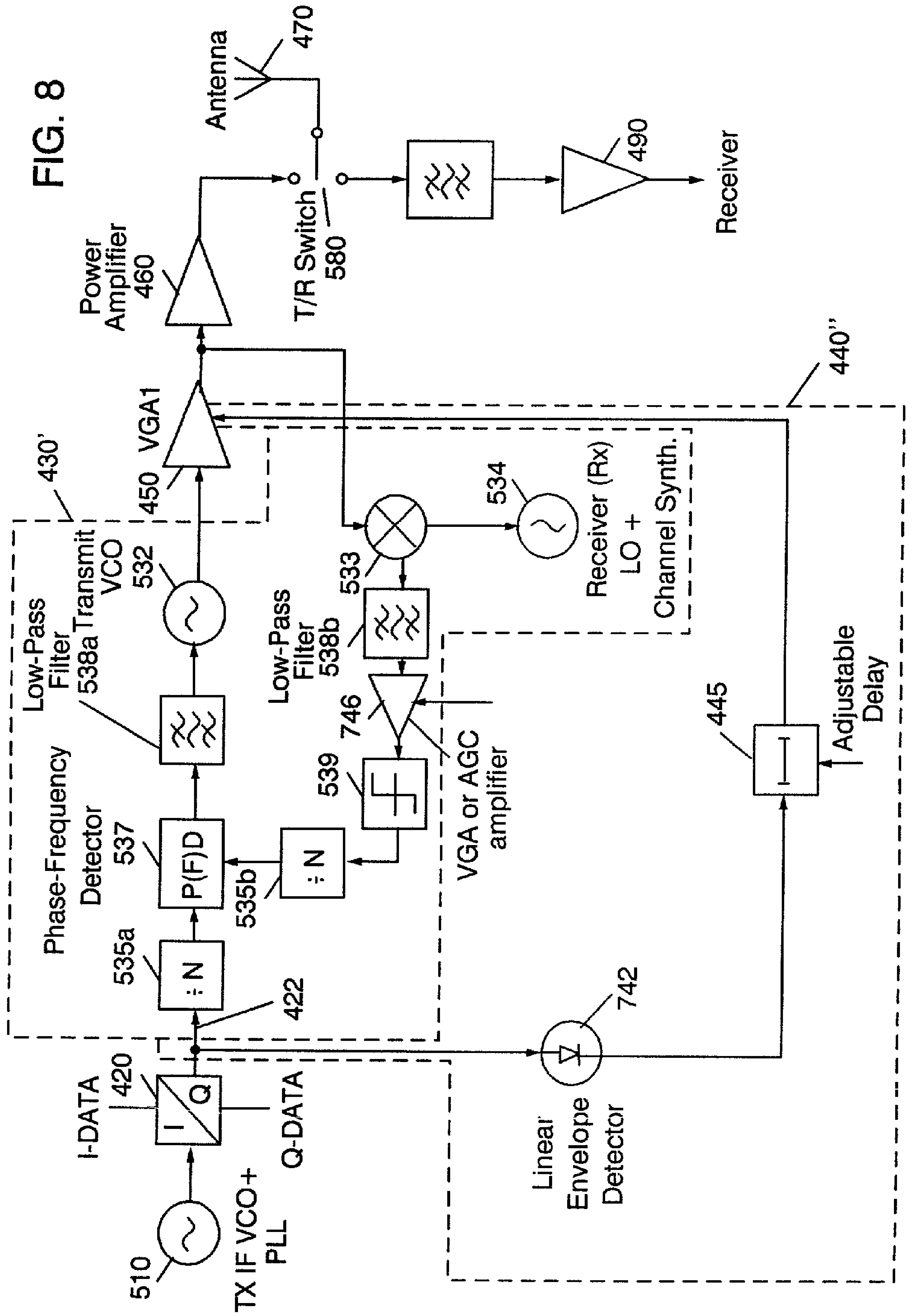
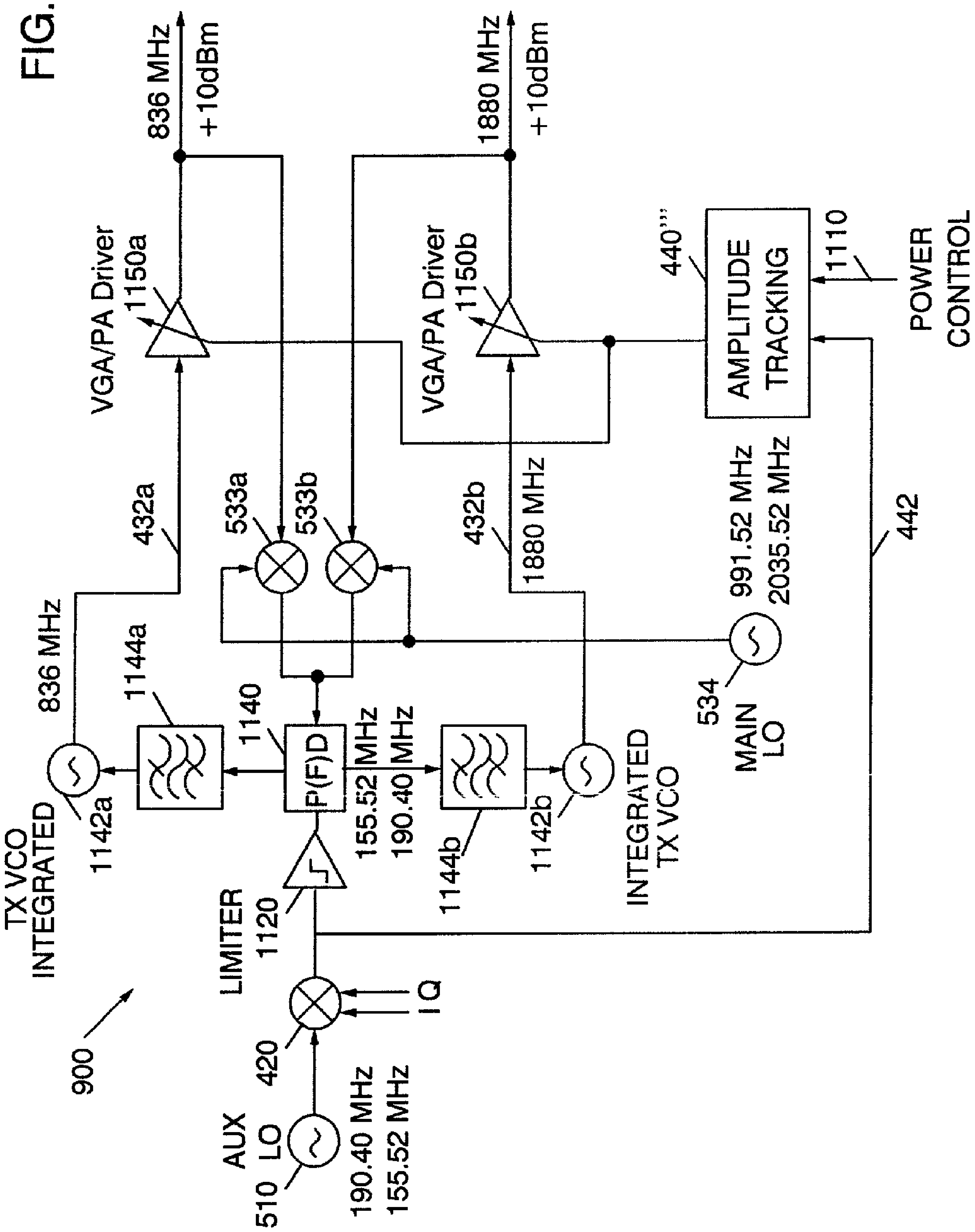

Antenna
470
Power Amplifier 460
480 Duplexer
490
Receiver
440''
430'
450 VGA1
Transmit VCO 532
534
Receiver (Rx) LO + Channel Synth.
533
Low-Pass Filter 538a
Low-Pass Filter 538b
746
Phase-Frequency Detector 537
P(F)D
539
535b
÷ N
VGA or AGC amplifier
445
Adjustable Delay
535a
÷ M
422
742
I-DATA
420
I
Q
Q-DATA
510
TX IF VCO+ PLL
Linear Envelope Detector

FIG. 8



Antenna
470
490
Receiver
Power
Amplifier
460
T/R Switch
580
VGA1
450
430'
440''
Transmit
VCO
532
Low-Pass
Filter
538a
533
534
Receiver (Rx)
LO +
Channel Synth.
Low-Pass
Filter
538b
746
VGA or AGC
amplifier
539
445
Adjustable
Delay
Phase-Frequency
Detector
537
P(F)D
÷ N
535b
535a
422
742
420
I-DATA
Q-DATA
I
Q
510
TX IF VCO+
PLL
Linear
Envelope
Detector

FIG. 9



836 MHz
+10dBm
1880 MHz
+10dBm
VGA/PA Driver
1150a
VGA/PA Driver
1150b
440'''
AMPLITUDE
TRACKING
1110
POWER
CONTROL
432a
533a
533b
432b
1880 MHz
991.52 MHz
2035.52 MHz
442
836 MHz
1144a
1140
P(F)D
155.52 MHz
190.40 MHz
1144b
1142b
INTEGRATED
TX VCO
534
MAIN
LO
TX VCO
INTEGRATED
1142a
LIMITER
1120
900
420
I Q
AUX
LO
510
190.40 MHz
155.52 MHz

FIG. 11

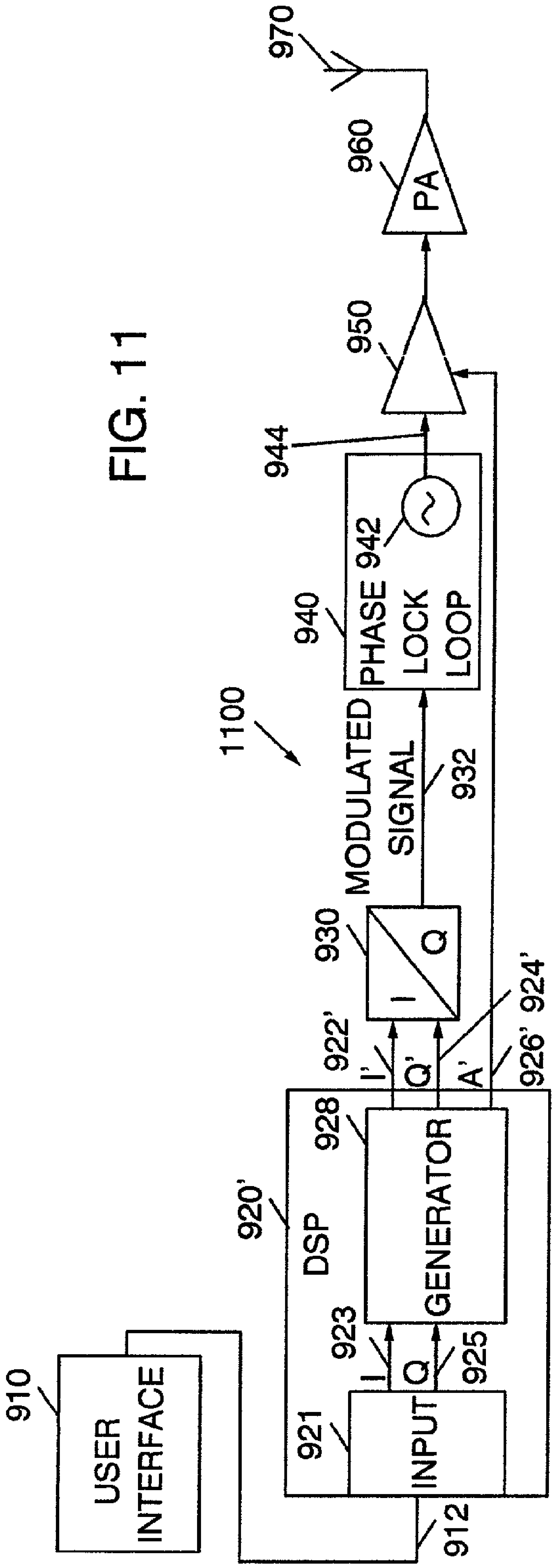

970
960
PA
950
944
PHASE
LOCK
LOOP
942
940
1100
MODULATED
SIGNAL
932
930
I
Q
922'
I'
Q'
A'
926'
924'
928
GENERATOR
920'
DSP
923
I
Q
925
921
INPUT
910
USER
INTERFACE
912

FIG. 13

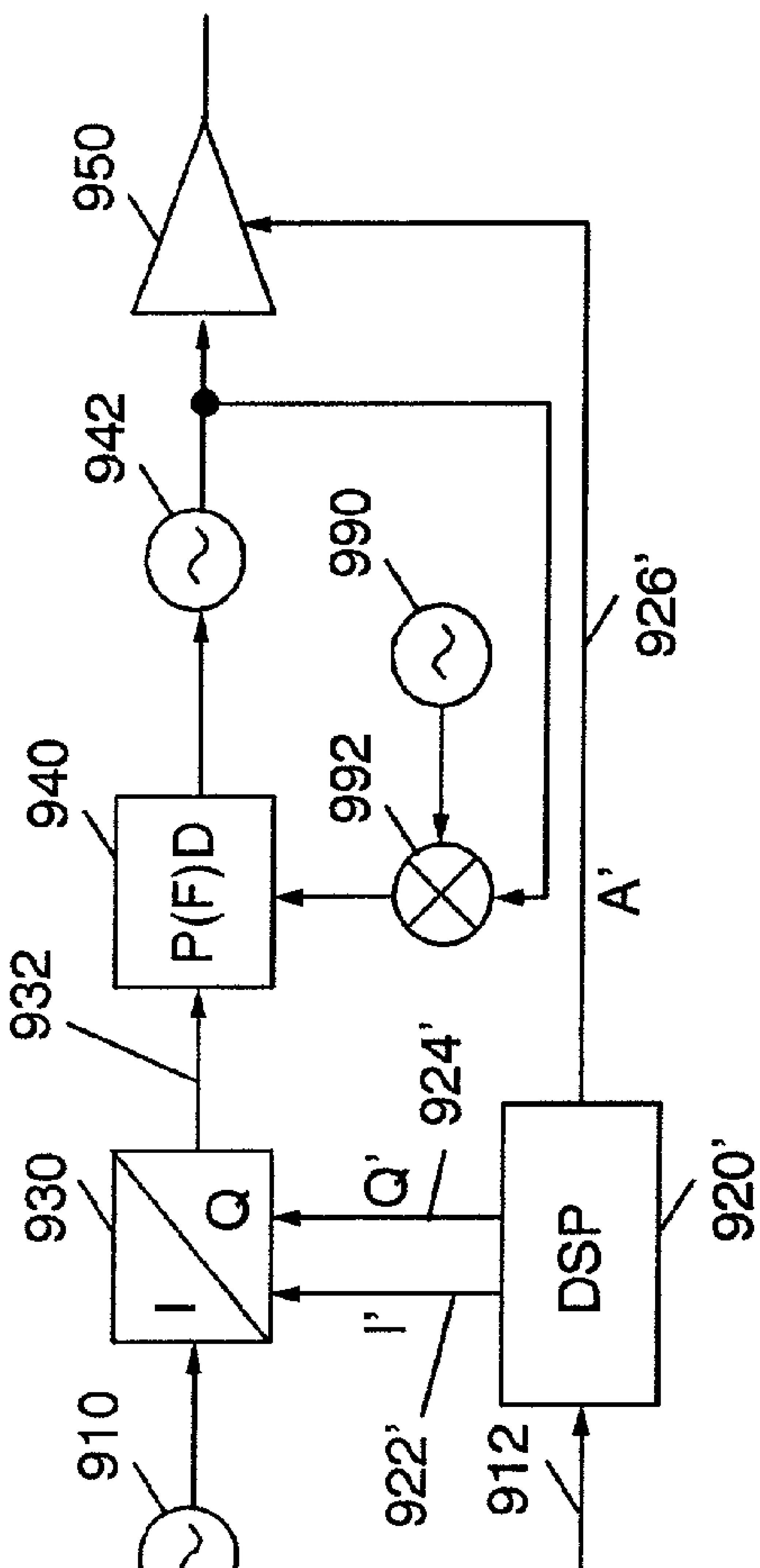
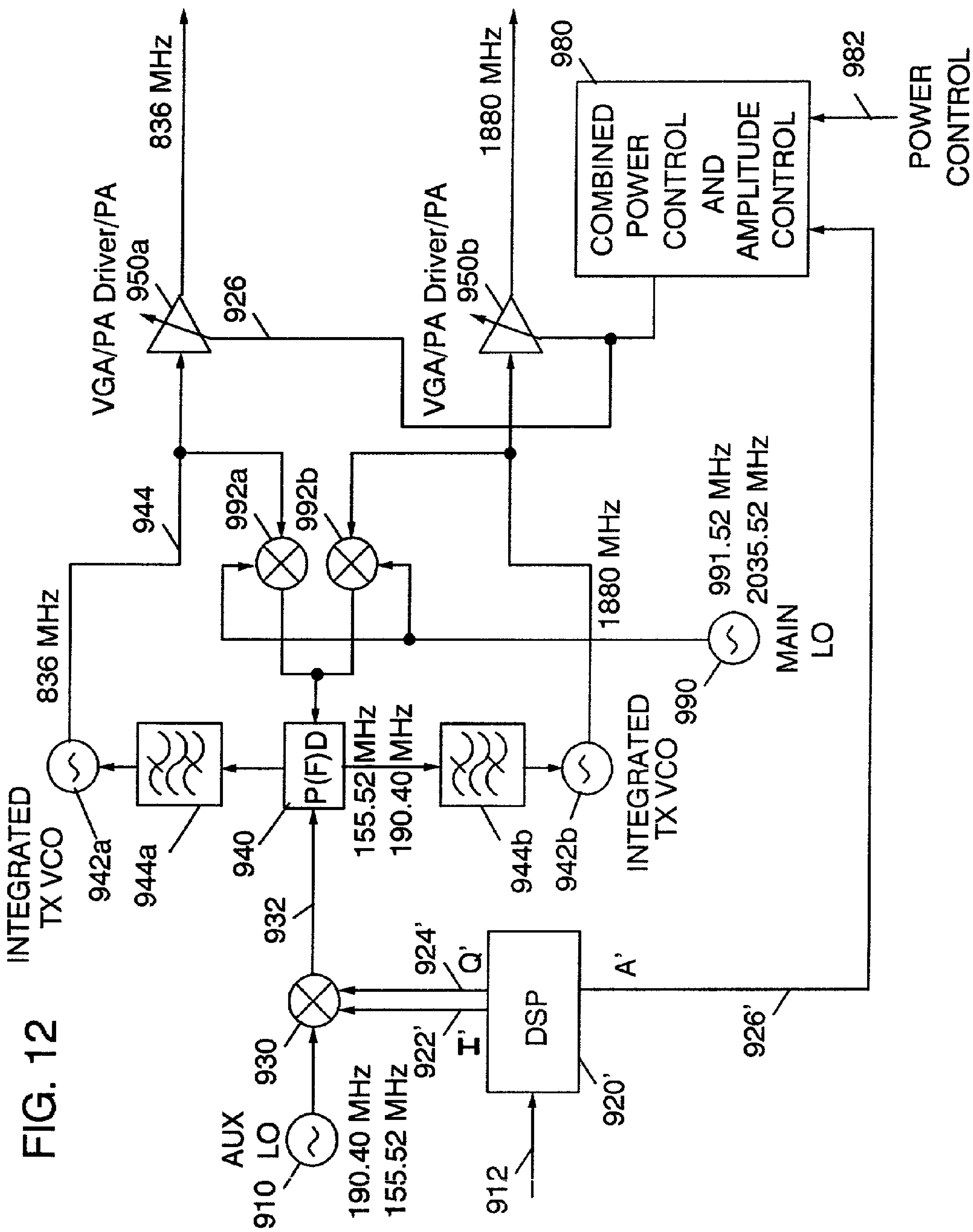

950
942
990
940
P(F)D
992
932
930
I
Q
Q'
924'
I'
922'
910
DSP
920'
912
A'
926'

FIG. 12



AUX LO
910
190.40 MHz
155.52 MHz
930
922'
I'
924'
Q'
DSP
920'
912
A'
926'
932
940
P(F)D
155.52 MHz
190.40 MHz
944a
944b
942a
942b
INTEGRATED TX VCO
INTEGRATED TX VCO
836 MHz
1880 MHz
944
992a
992b
991.52 MHz
2035.52 MHz
990
MAIN LO
VGA/PA Driver/PA
950a
VGA/PA Driver/PA
950b
926
836 MHz
1880 MHz
980
COMBINED POWER CONTROL AND AMPLITUDE CONTROL
982
POWER CONTROL

FIG. 14

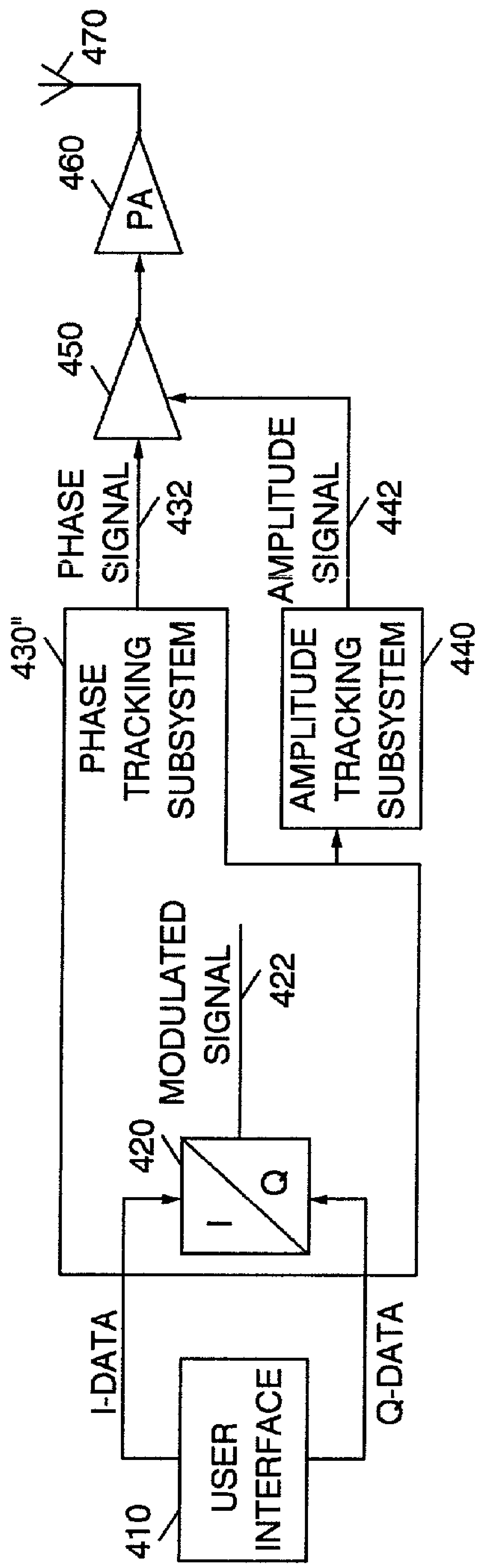

USER INTERFACE
410
I-DATA
Q-DATA
I
Q
420
MODULATED SIGNAL
422
PHASE TRACKING SUBSYSTEM
430"
AMPLITUDE TRACKING SUBSYSTEM
440
PHASE SIGNAL
432
AMPLITUDE SIGNAL
442
450
PA
460
470

FIG. 15

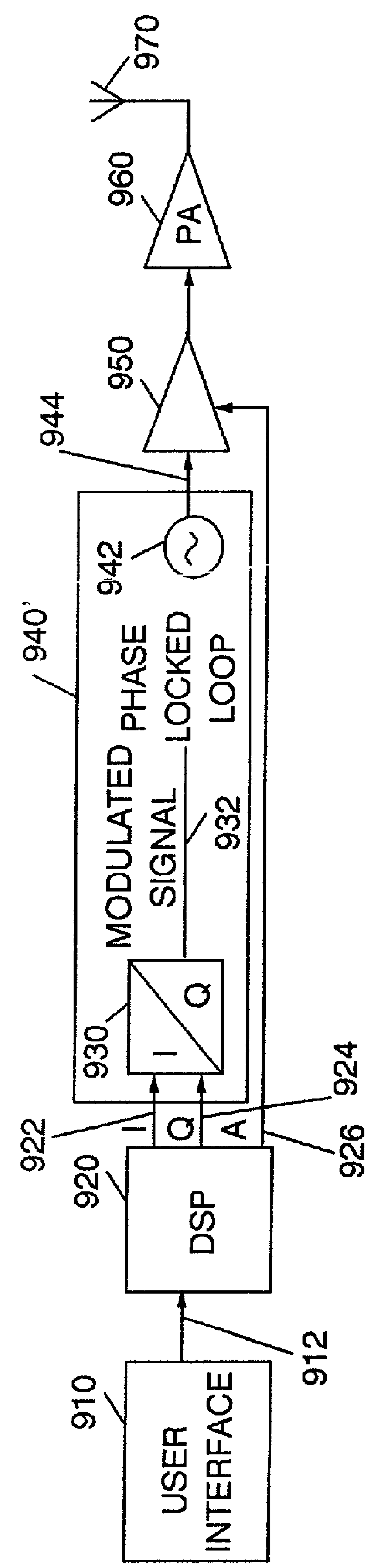
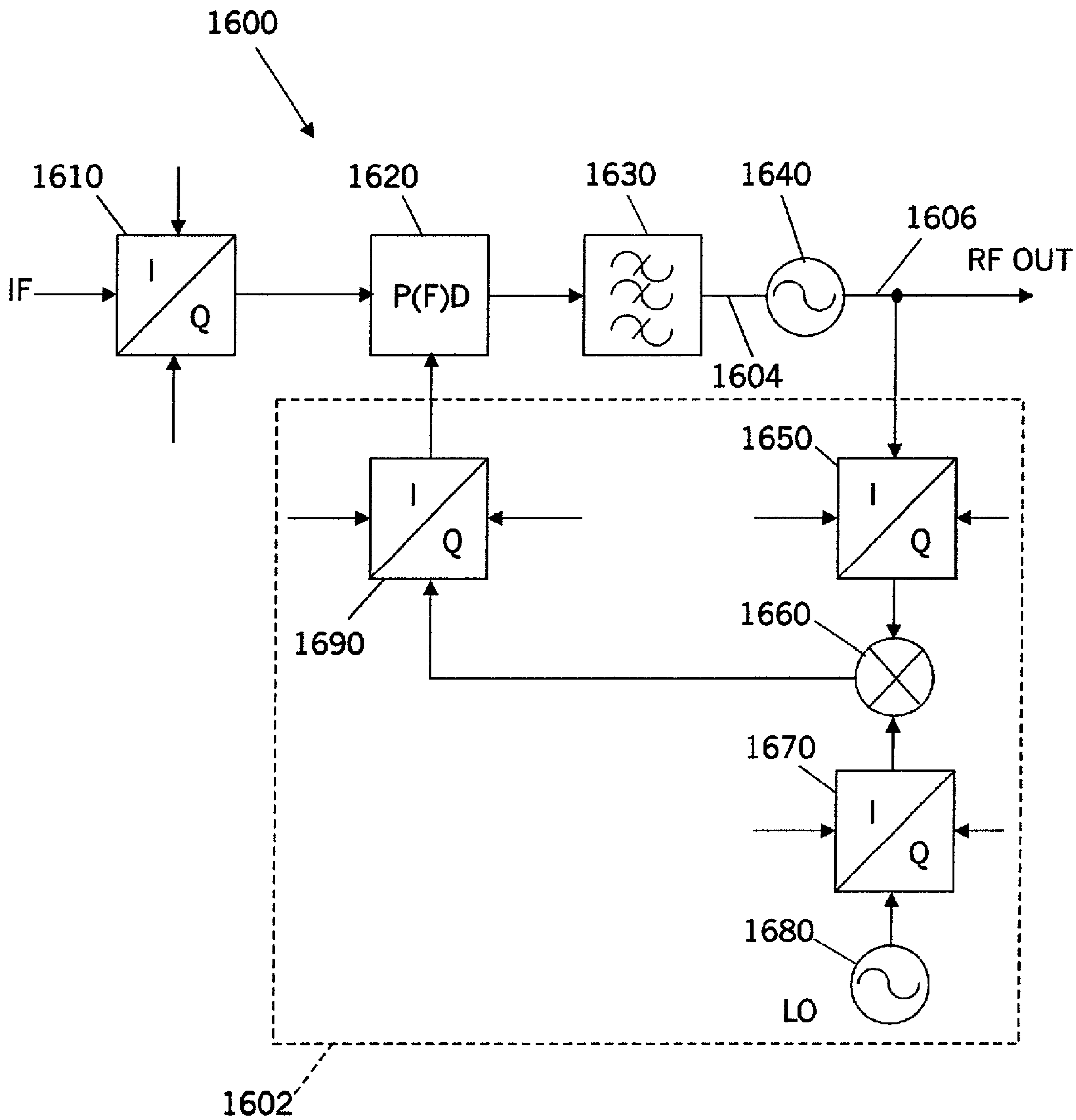
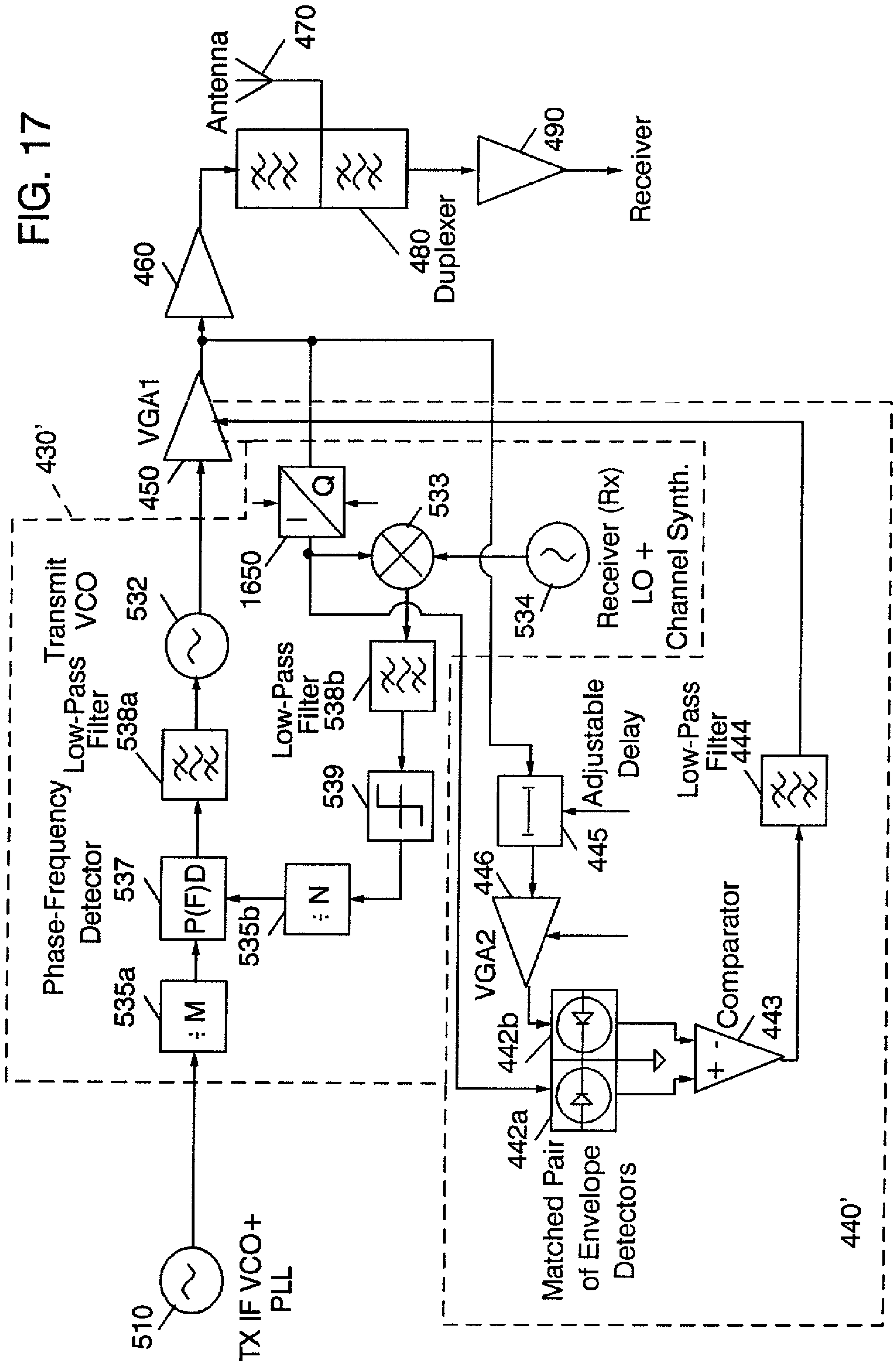

USER INTERFACE
910
912
DSP
920
I
Q
A
922
924
926
I
Q
930
MODULATED SIGNAL
932
PHASE LOCKED LOOP
940'
942
944
950
PA
960
970

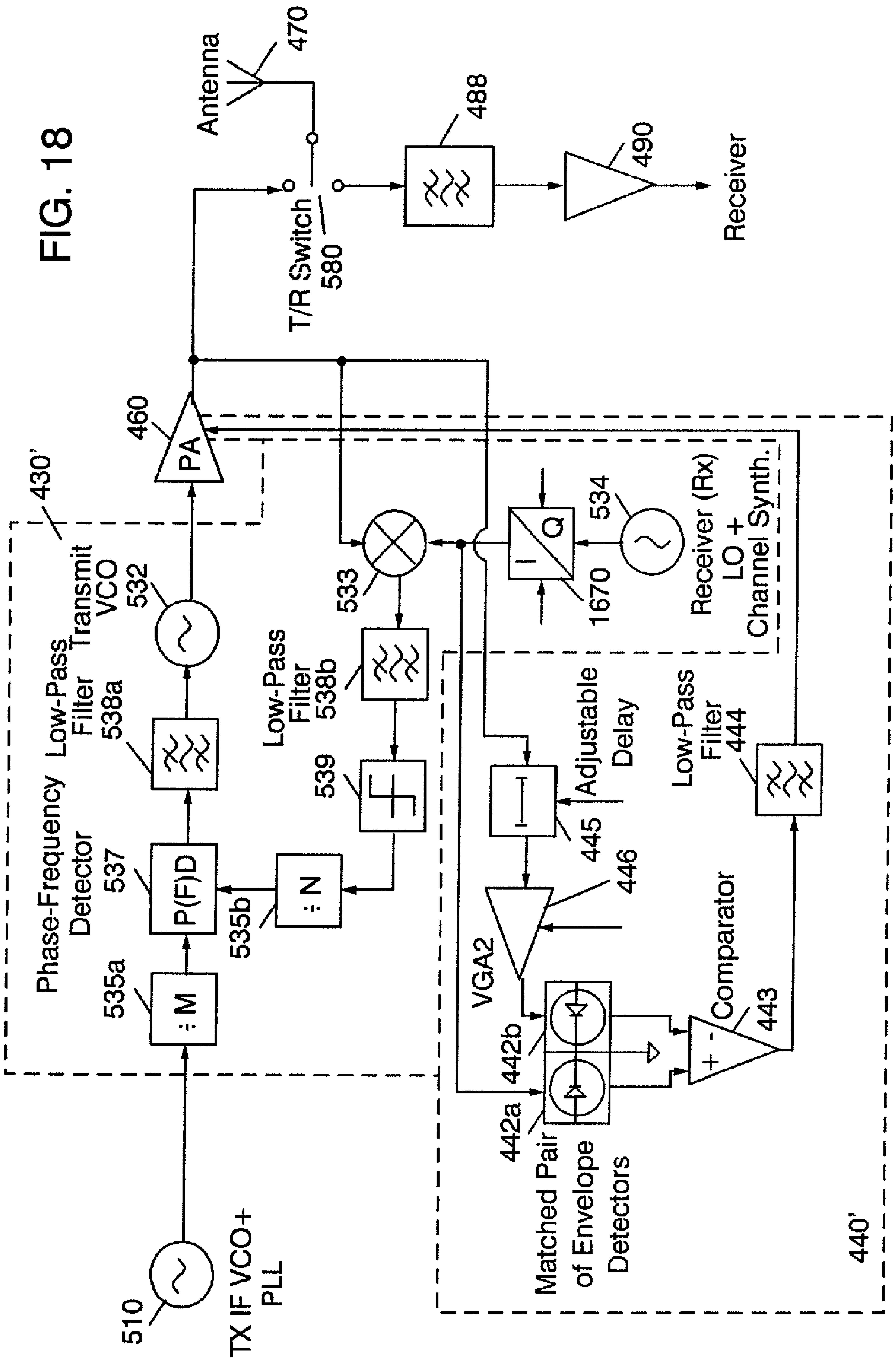
FIG. 16


1600
1610
1620
1630
1640
1606
RF OUT
IF
I
Q
P(F)D
1604
1650
1660
1690
1670
1680
LO
1602



Antenna
470
460
480
Duplexer
490
Receiver
430'
450
VGA1
Transmit VCO
532
1650
I
Q
533
Receiver (Rx) LO + Channel Synth.
534
Phase-Frequency Detector
537
P(F)D
Low-Pass Filter
538a
535a
÷ M
Low-Pass Filter
538b
539
÷ N
535b
Adjustable Delay
445
Low-Pass Filter
444
446
VGA2
Comparator
443
442b
442a
Matched Pair of Envelope Detectors
440'
510
TX IF VCO+ PLL

FIG. 17



Antenna
470
488
490
Receiver
T/R Switch
580
460
PA
430'
Transmit
VCO
532
Low-Pass
Filter
538a
Phase-Frequency
Detector
537
P(F)D
535a
÷ M
535b
÷ N
533
Low-Pass
Filter
538b
539
534
Receiver (Rx)
LO +
Channel Synth.
1670
I
Q
Adjustable
Delay
445
446
VGA2
Low-Pass
Filter
444
Comparator
443
442b
442a
Matched Pair
of Envelope
Detectors
440'
510
TX IF VCO+
PLL

FIG. 18

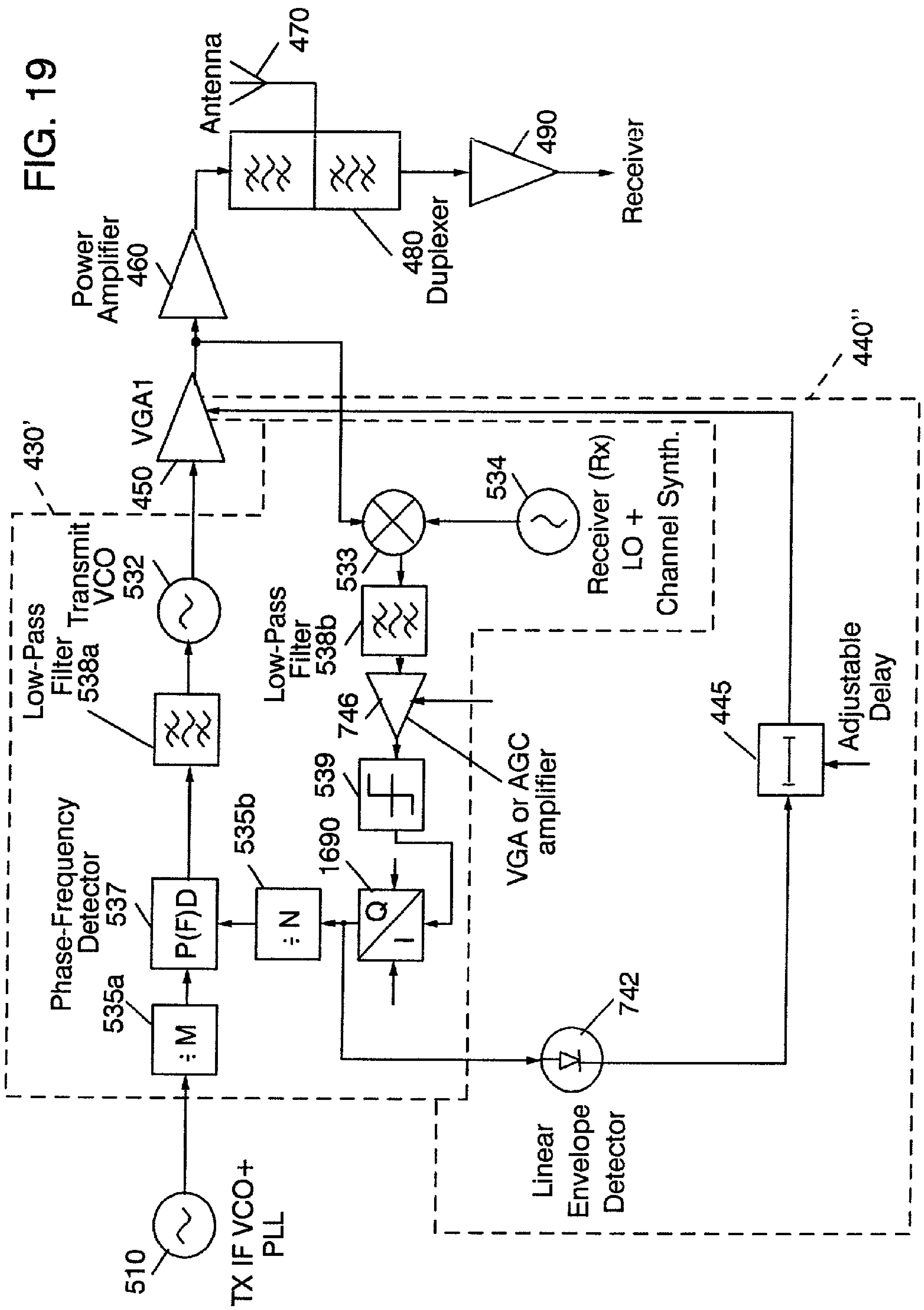

Antenna
470
480 Duplexer
490
Receiver
Power Amplifier 460
450 VGA1
430'
440''
Transmit VCO 532
Low-Pass Filter 538a
Phase-Frequency Detector 537
P(F)D
535a
÷ M
535b
÷ N
1690
Q
I
539
746
VGA or AGC amplifier
Low-Pass Filter 538b
533
534
Receiver (Rx) LO + Channel Synth.
445
Adjustable Delay
742
Linear Envelope Detector
510
TX IF VCO+ PLL

FIG. 19

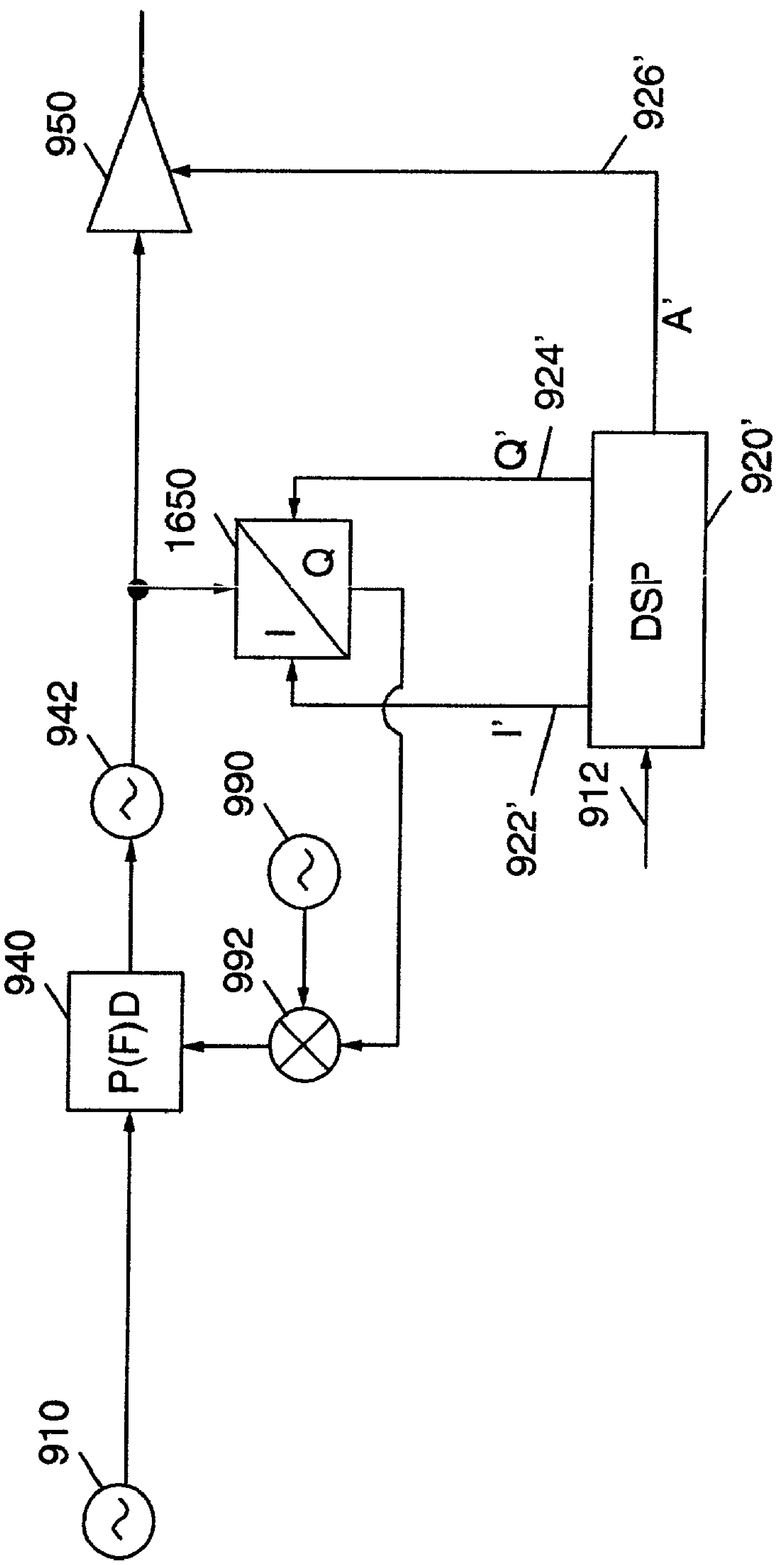


FIG. 20

FIG. 21

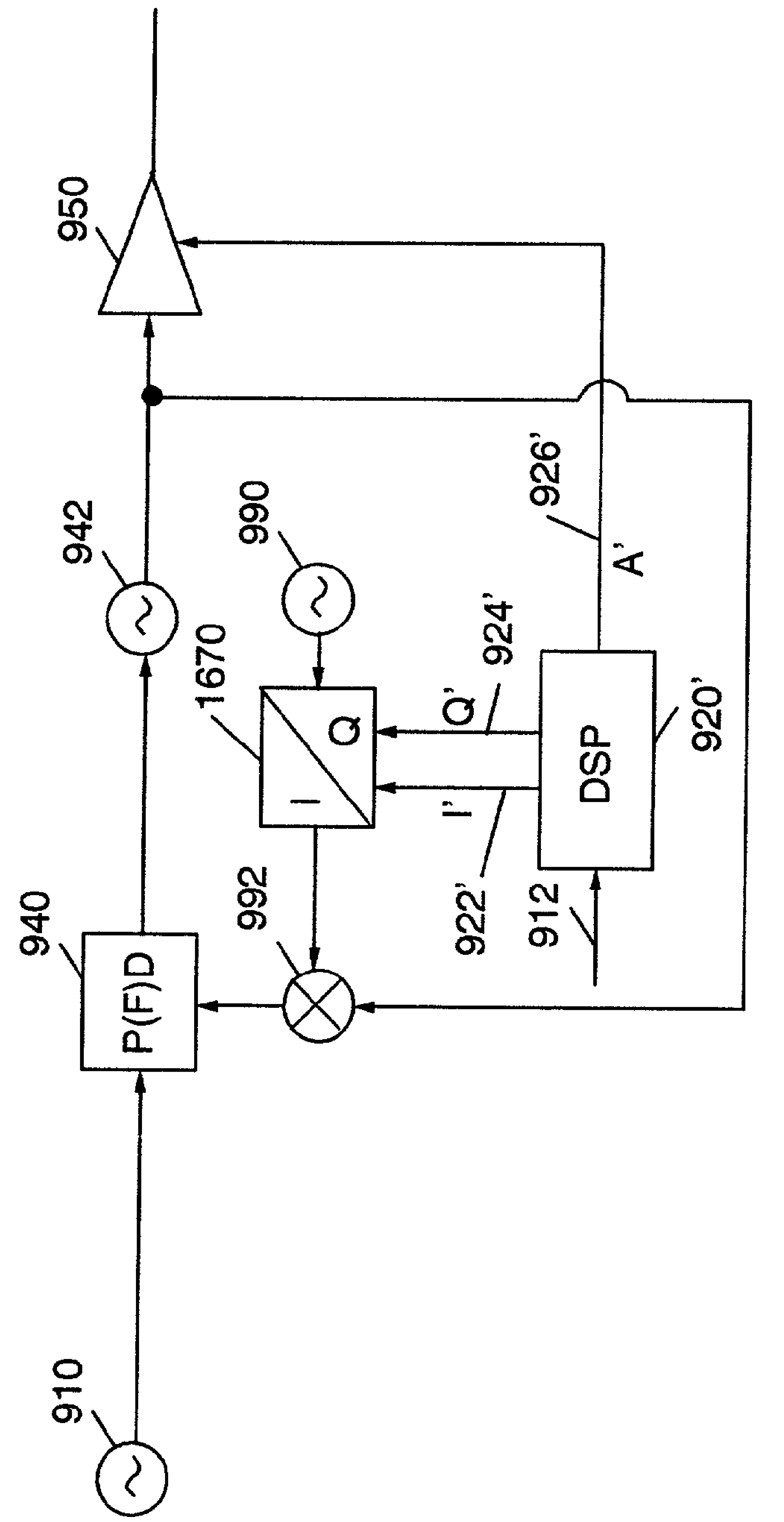
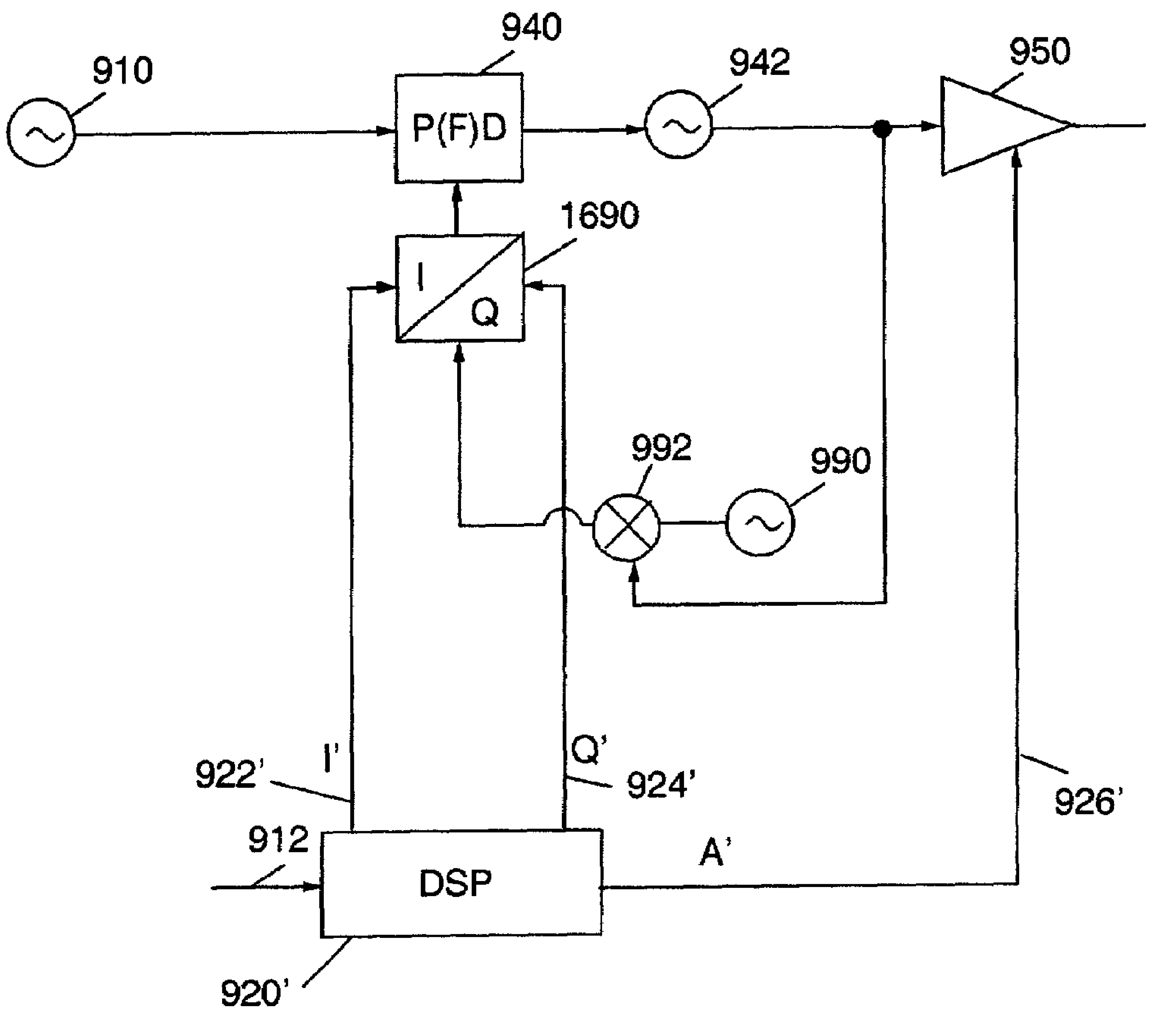


FIG. 22



IQ MODULATION SYSTEMS AND METHODS THAT USE SEPARATE PHASE AND AMPLITUDE SIGNAL PATHS AND PERFORM MODULATION WITHIN A PHASE LOCKED LOOP

CROSS REFERENCE TO RELATED APPLICATION

This application is a Continuation-in-Part (CIP) of application Ser. No. 09/703,037, filed Oct. 31, 2000, now U.S. Pat. No. 6,975,686 entitled IQ Modulation Systems and Methods That Use Separate Phase and Amplitude Signal Paths, assigned to the assignee of the present invention, the disclosure of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to modulation systems and methods, and more particularly to IQ modulation systems and methods.

BACKGROUND OF THE INVENTION

Modulation systems and methods are widely used in transmitters to modulate information including voice and/or data onto a carrier. The carrier may be a final carrier or an intermediate carrier. The carrier frequency can be in UHF, VHF, RF, microwave or any other frequency band. Modulators also are referred to as "mixers" or "multipliers". For example, in a wireless communications terminal such as a mobile radiotelephone, a modulator can be used for the radiotelephone transmitter.

FIG. **1** illustrates a conventional IQ modulator. As shown in FIG. **1**, an IQ modulator **110**, also referred to as a "quadraphase modulator" or a "quadrature modulator", includes a quadrature splitter **120**, also known as a 90° phase shifter, and a pair of multipliers **116***a*, **116***b* coupled to the quadrature splitter. A controlled oscillator **115**, such as a Voltage Controlled Oscillator (VCO), is coupled to the quadrature splitter **120** to produce 90° phased shifted oscillator signals. In-phase (I) data **111***a* and quadrature-phase (Q) data **111***b* are coupled to a respective multiplier or mixer **116***a*, **116***b*. Digital input data is converted to analog data by I Digital-to-Analog Converter (DAC) **114***a* and Q DAC **114***b*, respectively. The outputs of the respective DACs **114***a* and **114***b* are applied to the respective low pass filters **112***a* and **112***b* to provide the respective I and Q data inputs **111***a* and **111***b*. The modulator **110** modulates the input data on a carrier by summing the outputs of the multipliers **116***a*, **116***b* at a summing node **118**. The modulated carrier **113** is amplified by a power amplifier **122** and transmitted via an antenna **124**.

In modern wireless communications, wireless communications terminals such as mobile radiotelephones continue to decrease in size, cost and/or power consumption. In order to satisfy these objectives, it generally is desirable to provide IQ modulation systems and methods that can provide high power modulation while reducing the amount of battery power that is consumed. Unfortunately, the power amplifier **122** of an IQ modulator may consume excessive power due to efficiency limitations therein. More specifically, it is known to provide a linear class-A or class-AB power amplifier **122** that may have efficiencies as low as 30 percent or less. Thus, large amounts of battery power may be wasted as heat. Moreover, the noise figure of a conventional IQ modulator may be excessive so that high cost Surface Acoustic Wave (SAW) filters may need to be used.

FIG. **2** illustrates other conventional modulation systems. As shown in FIG. **2**, I-data and Q-data is modulated on an Intermediate Frequency (IF) signal supplied by a controlled oscillator such as a voltage controlled oscillator **202** by applying the I-data and Q-data and the output of the IF voltage controlled oscillator **202** to an IQ modulator **204**. The output of the modulator is then bandpass filtered by an IF bandpass filter **206**. A local oscillator **212** and an up-conversion mixer **214** are used to up-convert the output of the bandpass filter **206** to a desired radio frequency. The output of the up-conversion mixer **214** is bandpass filtered by a radio frequency bandpass filter **216** to reduce noise and spurious levels. The filtered signal is then amplified using a variable gain amplifier **222** to provide the appropriate signal level to a power amplifier **226** which delivers the signal to an antenna **232** via a duplex filter **234**. Additional RF bandpass filtering **224** may be used between the variable gain amplifier **222** and the power amplifier **226**.

FIG. **3** is a block diagram of other conventional modulation systems wherein like elements to FIG. **2** are labeled with like numbers. The approach shown in FIG. **3** is similar to that of FIG. **2** except the IF signal is up-converted to the RF band first and then modulated in the IQ modulator **204**.

Unfortunately, in either of the conventional approaches of FIGS. **2** or **3**, the IQ modulator **204**, up-conversion mixer **214** and/or the variable gain amplifier **222** may generate significant amounts of additive noise and spurious levels which may need to be filtered before the signal reaches the power amplifier **226**. Systems of FIGS. **2** and **3** also may suffer from high current consumption and may need to use an excessive number of filters to meet the desired output spurious level and desired noise level.

It also is known to separately modulate the amplitude and phase of an input signal using an "rTheta" technique. In the rTheta technique, the phase is modulated at the oscillator, and the amplitude is modulated at the power amplifier stage. Unfortunately, the rTheta technique may require the oscillator phase locked loop to support the phase modulation bandwidth. With wide bandwidth radiotelephone signals such as TDMA and CDMA signals, it may be increasingly difficult to provide the requisite bandwidth in the oscillator phase locked loop.

SUMMARY OF THE INVENTION

Embodiments of the present invention provide modulation systems and methods having separate phase and amplitude signal paths. In particular, according to embodiments of the present invention, a digital signal processor generates in-phase, quadrature-phase and amplitude signals from a baseband signal. A modulator modulates the in-phase and quadrature-phase signals to produce a modulated signal. A phase locked loop is responsive to the modulated signal. The phase locked loop includes a controlled oscillator having a controlled oscillator input. An amplifier includes a signal input, an amplitude or gain control input and an output. The signal input is responsive to the controlled oscillator output and the amplitude control input is responsive to the amplitude signal.

In other embodiments according to the present invention, the in-phase and quadrature-phase signals are normalized in-phase and quadrature-phase signals. In these embodiments, the digital signal processor generates the normalized in-phase signal as a respective sine or cosine of an angle theta and generates the normalized quadrature-phase signal as a respective cosine or sine of the angle theta, where theta is an angle whose tangent is the quadrature-phase signal divided by the in-phase signal. The amplitude signal also is normalized and is generated as the square root of the sum of the in-phase signal squared and the quadrature-phase signal squared.

In other embodiments, the modulator is a first modulator and the modulated signal is a first modulated signal. These embodiments further comprise a second modulator that is responsive to the controlled oscillator output to produce a second modulated signal wherein the phase locked loop also is responsive to the second modulated signal. Moreover, in other embodiments a power control signal also is provided and the amplitude control input is responsive to the amplitude signal and to the power control signal.

In yet other embodiments, the phase locked loop that is responsive to the modulated signal includes a controlled oscillator having a controlled oscillator output and a feedback loop between the controlled oscillator input and the controlled oscillator output. The feedback loop includes a mixer that is responsive to a local oscillator. In these embodiments, the modulator may be placed in the phase locked loop. In some embodiments, the modulator may be placed in the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input. Thus, modulation may take place within the phased lock loop instead of, or in addition to, taking place prior to the phased lock loop.

Other modulation systems and methods according to embodiments of the invention include a quadrature modulator that modulates in-phase and quadrature-phase signals to produce a modulated signal. A phase tracking subsystem is responsive to the quadrature modulator to produce a phase signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal. An amplitude tracking subsystem is responsive to the modulator to produce an amplitude signal that is responsive to amplitude changes in the modulated signal and that is independent of the phase changes in the modulated signal. An amplifier has a signal input, an amplitude control input and an output. The signal input is responsive to the phase signal and the amplitude control input is responsive to the amplitude signal.

In other embodiments, the phase tracking subsystem comprises a phase locked loop that is responsive to the modulated signal. The phase locked loop includes a controlled oscillator having a controlled oscillator output that produces the phase signal.

In other embodiments, the amplitude tracking system includes an automatic gain control subsystem that is responsive to the modulated signal to produce the amplitude signal. In some embodiments, the automatic gain control subsystem comprises a first envelope detector that is responsive to the modulated signal, a second envelope detector that is responsive to the phase locked loop and a comparator that is responsive to the first and second envelope detectors to produce the amplitude signal. In yet other embodiments, the automatic gain control subsystem comprises a first envelope detector that is responsive to the modulated signal, a second envelope detector that is responsive to the amplifier and a comparator that is responsive to the first and second envelope detectors to produce the amplitude signal. In still other embodiments, the amplitude tracking system comprises an envelope detector that is responsive to the modulated signal to produce the amplitude signal.

In still other embodiments, the phase tracking system comprises a phase locked loop that is responsive to the modulated signal. The phased lock loop includes a controlled oscillator having a controlled oscillator input and a controlled oscillator output that produces the phase signal. The phase locked loop also includes a feedback loop between the controlled oscillator input and the controlled oscillator output. The feedback loop includes a mixer that is responsive to a local oscillator. The modulator is placed in the phase locked loop. In some embodiments, the modulator is placed in the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input. Accordingly, the modulation may take place within the feedback loop in addition to taking place before the phase locked loop.

In all of the above-described embodiments, an optional power amplifier may be included that is responsive to the output of the amplifier having a signal input, an amplitude control input and an output. Alternatively, a power amplifier itself may have the signal input, the amplitude control input and the output. A transmit antenna is responsive to the amplifier or power amplifier.

Moreover, in all of the above-described embodiments, the amplifier may include a variable gain amplifier and/or a power amplifier, at least one of which includes an amplitude control input that is responsive to the amplitude signal. When both a variable gain amplifier and a power amplifier are used, the variable gain amplifier may precede the power amplifier or the power amplifier may precede the variable gain amplifier, regardless of which one includes the amplitude control input. Additional variable gain amplifiers and/or power amplifiers also may be included in the amplifier.

Finally , a user interface may be provided that generates the baseband signal or the in-phase and quadrature-phase signals in response to user input to provide a wireless communications terminal such as a radiotelephone.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**–**3** are block diagrams of conventional IQ modulators; and

FIGS. **4**–**22** are block diagrams of IQ modulation systems and methods according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout. It will be understood that when an element is referred to as being "between" other elements, it can be directly between the other elements or intervening elements may also be present. In contrast, when an element is referred to as being "directly between" other elements, there are no intervening elements present.

Embodiments of the present invention stem from a realization that potential shortcomings of the systems of FIGS. **2** and **3** may arise from the two mixing (heterodyning) operations that are performed. In particular, a frequency mixing occurs in the up-conversion mixer **214** and in the IQ modulator **204** which may include two double balanced mixers. The frequency mixing may inherently generate high spurious levels and/or noise. Moreover, while some spurious levels far from the transmit carrier can be attenuated by the filters **206**, **216** and **224**, other levels may be within the allowed transmission band of the transmitter and may not be filtered. Moreover, the amount of filtering to reduce the output noise and spurious levels may exceed that which can be achieved with a single RF filter. Thus, multiple filters may need to be placed in the modulator. This also can add cost and/or space to the system. Finally, in order to reduce distortion of the modulated signal (information plus the carrier) and to meet transmit voice quality needs, the up-conversion mixer **214**, the IQ modulator **204** and the variable gain amplifier **222** may run at high current levels, which can reduce the operating time and generate excessive heat for portable wireless communication terminals.

Embodiments of the present invention can reduce the output noise and/or spurious levels so that the need for additional filters may be reduced and preferably may be eliminated. Moreover, the current consumption of an IQ modulator can be reduced while still meeting a desired linearity.

Referring now to FIG. **4**, modulation systems and methods according to embodiments of the present invention are shown. As shown in FIG. **4**, these embodiments of modulation systems and methods **400** include a quadrature (IQ) modulator **420** that modulates in-phase and quadrature-phase signals, referred to as I-data and Q-data, that may be generated by a user interface **410** in response to user commands, to produce a modulated signal **422**. A phase tracking subsystem **430** is responsive to the quadrature modulator **420** to produce a phase signal **432** that is responsive to phase changes in the modulated signal **422** and that is independent of amplitude changes in the modulated signal **422**. An amplitude tracking subsystem **440** also is included that is responsive to the modulator **420** to produce an amplitude signal **442** that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal **422**. An amplifier **450** includes a signal input, an amplitude or gain control input and an output. The signal input is responsive to the phase signal **432**. The amplitude control input is responsive to the amplitude signal **442** and the output is applied to a transmit antenna **470**, optionally via a power amplifier **460**. Alternatively, the amplifier **450** may be a power amplifier.

Referring now to FIG. **5**, other modulation systems and methods according to embodiments of the present invention are shown. As shown in FIG. **5**, these modulation systems and methods **500** include an IQ modulator **420**, a phase tracking subsystem **430'**, an amplitude tracking subsystem **440'**, an amplifier **450**, a power amplifier **460** and an antenna **470**. As shown, the transmitter carrier frequency is generated using a fundamental radio frequency controlled oscillator such as a voltage controlled oscillator **532** which can have an extremely high signal-to-noise ratio, on the order of −165 dBc/Hz at 45 MHz away. The output signal level is controlled using an amplifier **450** such as a saturated variable gain amplifier. The information signal (I-data and Q-data) is first modulated on an IF signal using the IQ modulator **420**. The IF signal is generated by a separate fundamental controlled oscillator such as a voltage controlled oscillator **510**. The modulated signal then is provided to separate amplitude and phase tracking subsystems in the form of amplitude and phase tracking loops **440'** and **430'**, respectively. The modulated IF signal **422** acts as a reference for amplitude and phase comparators in the two corresponding tracking loops **440'** and **430'**. The RF output signal from the amplifier **450** is mixed down to the IF frequency using a system local oscillator **534**. The VCO **532** is phase locked using the phase locked loop that includes dividers **535***a*, **535***b*, a phase-frequency detector or a phase detector **537**, a pair of low pass filters **538***a* and **538***b*, and a limiter **539**. This phase locked loop acts as the channel synthesizer for the transmitter. The output of the mixer **533** is low pass filtered via low pass filter **538***b* and fed to the limiter **539** along with the modulated reference IF signal **534**.

In the phase tracking loop **430'**, optional RF dividers **535***a* and **535***b* are placed in the reference and compare arms of the phase-frequency detector **537** to divide by M and N respectively. Since practical implementation of phase-frequency detectors at high frequencies may be difficult, this can allow for the lowering of the comparison frequency and can have negligible effect on the phase comparison. It also will be understood that the dividers **535***a* and **535***b* may be set such that M=N, or M=N=1, or may be eliminated.

In the amplitude-tracking loop **440'**, a pair of matched envelope detectors **442***a* and **442***b* are used to compare the amplitude level of the down-converted IF signal or other signal from the phase locked loop to that of the modulated signal **422**. Good matching between the two envelope detectors **442***a* and **442***b* may be provided to reduce AM offsets in the loop. Also, an adjustable constant delay element **445** may be introduced in the amplitude tracking loop **440'** to match the total group delay for the amplitude and phase signals. If the total delay is not matched, the output signal may not have the desired modulation characteristics.

Since the output power level of the transmitter is controlled by the amplifier **450** (VGA**1**) over a wide range, the total loop gain may change for the amplitude and phase tracking loops. In the phase tracking loop, the limiter **539** and/or the limiting action of the phase detector **537** can maintain constant loop gain, while in the amplitude tracking loop **440'**, a separate variable gain amplifier **446** (VGA**2**) with the opposite gain versus control voltage slope as the amplifier **450** is used. As the gain of VGA**1** **450** is reduced to reduce output signal level, the gain of VGA**2** **446** may be increased by the same amount to keep the signal level into the matched envelope detectors **442***a*, **442***b* nearly constant. Otherwise, the envelope detectors **442***a*, **442***b* may need to have good matching over a very large (>50 dB) range of signal levels at the input. Such wide dynamic range envelope detectors may be difficult to implement. One additional potential advantage of embodiments of FIG. **5** is that the AM/PM distortion in VGA**1** **450** is compensated in the phase tracking loop **430'**. This can help achieve low phase and amplitude error over a wide range of output power levels.

The output signals of the phase and amplitude detectors are filtered using low-pass filters **538***a*, **444** which can have bandwidths large enough to pass the modulation signal (baseband) but narrow enough to suppress noise and spurious levels outside the modulation bandwidth. In effect, the low-pass filters **538***a*, **538***b* and **444** in the phase and amplitude tracking loops **440'** and **430'** can act as bandpass filters on the RF transmit carrier signal with very narrow bandwidth (i.e., very high-Q). For example, for 30 kHz modulation bandwidth (common to digital wireless phones), the low-pass filter bandwidth can be less than 1 MHz. Therefore, the low-pass filter in the loop can be equivalent to a bandpass filter centered at the transmit frequency (e.g., 825 MHz) having a bandwidth of less than 1 MHz (Q>825).

The noise and spurious levels outside the 1 MHz bandwidth around the carrier are attenuated according to the attenuation characteristics of the low-pass filters in the tracking loops. Such low-pass filters can be implemented with resistors and capacitors, and thus can eliminate the need for expensive, multiple SAW filters.

Direct amplitude modulation of power amplifiers (especially saturated class-D power amplifiers) may be known. Some embodiments of the invention can provide electrical isolation between the modulation loop and the antenna. For example, embodiments of FIG. **5** can utilize the power amplifier **460** as an isolator providing electrical isolation between the antenna **470** and the transmit modulator. In this case, the efficiency of the amplifier (VGA**1**) **450** may not be as important to the overall power consumption. Therefore, it can be easier to implement simultaneous AM modulation and large power control range in VGA**1**. The amplifier **450** can be designed to operate in a fixed high-efficiency, linear mode without the need for dynamic bias adjustment. Alternatively, other embodiments can amplitude modulate the power amplifier itself. This can provide enhanced linearity margin and/or enhanced efficiency by utilizing a saturating power amplifier and restoring envelope amplitude through modulation of its supply.

FIG. **6** depicts embodiments of the present invention in a half-duplex system such as a TDMA-only IS-136 terminal or an EDGE terminal. In this case, the signal-to-noise ratio of the transmitter can be high enough so that the duplexer filter **480** of FIG. **5** can be replaced by a transmit-receive (T/R) switch **580** in the transmit path. Also in FIG. **6**, the power amplifier **460** itself is amplitude modulated.

It also will be understood by those having skill in the art that in FIGS. **5** and **6**, the input to the mixer **533** may be taken between the VCO **532** and the amplifier **450** rather than between the output of the amplifier **450** and the power amplifier **460** as illustrated.

FIG. **7** is a block diagram of other modulation systems and methods according to embodiments of the invention. In these embodiments, the amplitude tracking subsystem **440"** is implemented as a direct modulation or an open loop. This may be accomplished, for example, if an amplifier **450** having a linear voltage control characteristic is used. Such a circuit is feasible with integrated circuit design techniques. For embodiments of FIG. **7**, the divide ratio of the phase locked loop is one so that M and N are set to 1 or no dividers **535***a*, **535***b* are used. The IF amplifier **746** after the down-converting mixer **533** can be either a variable gain amplifier or an AGC amplifier. This amplifier **746** may be used in order to reduce the input operating range of the limiter **539**. The AM/PM distortion of the limiter **539** thereby can be reduced. In FIG. **7** the amplitude tracking subsystem **440"** includes an envelope detector **742** such as a diode and an adjustable delay **445**.

FIG. **8** depicts embodiments that can be used in a half-duplex system such as a TDMA-only IS-136 terminal or an EDGE terminal. In FIG. **8**, the signal-to-noise ratio of the transmitter can be high enough so that the duplexer filter **480** can be replaced by a transmit-receive (T/R) switch **580** in the transmit path that couples to a receiver amplifier **490**.

It will be understood that if the phase-frequency detector **537** is difficult to implement as a low current standard integrated circuit solution then a standard active analog phase detector such as a Gilbert cell mixer can be used. Assisted acquisition techniques then may be used to provide fast lock times for the PLL.

FIG. **9** is a block diagram of modulation systems and methods according to other embodiments of the present invention. FIG. **9** illustrates dual mode modulation systems and methods **900** that can produce cellular and PCS signals. As shown in FIG. **9**, a phase locked loop includes phase frequency detector or phase detector **1140** and a low pass filter **1144***a*, **1144***b* and a controlled oscillator such as a VCO **1142***a*, **1142***b* for each mode. A main local oscillator **534** and a pair of mixers **533***a*, **533***b* also are provided. An amplitude tracking subsystem **440'"** also may be responsive to a power control signal **1110**. A pair of variable gain amplifiers and/or power amplifiers **1150***a*, **1150***b* may be provided. A limiter **1120** also is provided between the modulator **420** and the phase frequency detector **1140**.

In summary, embodiments of FIGS. **4**–**9** can deliver low-distortion complex modulation signals containing both amplitude and phase information, with very high signal-to-noise ratio (for example on the order of −165 dBc/Hz at 45mHz offset) to a power amplifier. These embodiments can reduce or eliminate the need for SAW filters that are traditionally used in conventional digital radio transmitter architectures. They also can reduce power consumption and spurious products compared to the conventional up-mixing transmitters.

Referring now to FIG. **10**, a block diagram of other embodiments of modulation systems and methods according to the present invention is shown. As shown in FIG. **10**, these modulation systems and methods **1000** include a Digital Signal Processor (DSP) **920** that generates in-phase (I), quadrature-phase (Q) and amplitude (A) signals **922**, **924** and **926**, respectively, from a baseband signal **912** that may be generated by a user interface **910**. A modulator such as an IQ modulator **930** modulates the in-phase and quadrature-phase signals **922** and **924**, respectively, to produce a modulated signal **932**. A phase locked loop **940** is responsive to the modulated signal. The phase locked loop **940** includes a controlled oscillator **942** having a controlled oscillator output **944**. An amplifier **950** includes a signal input, an amplitude or gain control input and an output. The signal input is responsive to the controlled oscillator output **944** and the amplitude control input is responsive to the amplitude signal **926**. An optional power amplifier **960** is responsive to the output of the amplifier **950**. A transmit antenna is responsive to the power amplifier **960** and/or amplifier **950**.

FIG. **11** illustrates other modulation systems and methods **1100** according to embodiments of the present invention. As shown in FIG. **11**, the digital signal processor **920'** generates in-phase I and quadrature-phase Q signals **923** and **925**, respectively, from a baseband signal **912** at the input **921** thereof. A generator **928** within the digital signal processor **920'** then generates normalized in-phase (I') and quadrature-phase (Q') signals **922'** and **924'** and a normalized amplitude signal **926'**. It will be understood that the generator **928** may be embodied as a hardware and/or software module in the digital signal processor **920'**, and that the signals **922'**, **924'** and **926'** may be generated directly from the baseband signal **912**, without the need to generate the intermediate signals **923**, **925**. The normalized in-phase and quadrature signals **922'** and **924'** are applied to a modulator such as an IQ modulator **930**, such that the modulated signal **936** is of constant amplitude, followed by a phase locked loop **940**, amplifier **950**, optional power amplifier **960** and antenna **970** as was described in connection with FIG. **9**. The normalized amplitude signal A' is applied to the gain control input of the amplifier **950**.

Still referring to FIG. **11**, in embodiments of the invention, the digital signal processor **920'** generates the normalized in-phase signal I'**922'** as a cosine of an angle θ and generates the normalized quadrature-phase signal Q'**924'** as a sine of the angle θ, where the angle θ is an angle whose tangent is the quadrature-phase signal **925** divided by the in-phase signal **923**. Moreover, the normalized amplitude signal **926'** is generated as the square root of the sum of the in-phase signal I **923** squared and the quadrature-phase signal Q **925** squared. It will be understood that the sine and cosine functions may be interchanged from that which is described above.

Embodiments of FIGS. **10** and **11** can mathematically manipulate I, Q and A signals to allow reduced distortion in modulators. Conventionally, I and Q signals come from the baseband section of a wireless terminal carrying the modulating information that represents a voice and/or data signal that is to be transmitted. I and Q signals also can be represented as amplitude and phase signals. As was already described, a conventional transmitter modulates a VCO with this I and Q information and then amplifies the composite signal and up-converts the frequency to the transmit frequency. In sharp contrast, embodiments of FIGS. **10** and **11** perform numerical generation of I, Q and A signals from baseband. Moreover, embodiments of FIG. **11** generate normalized I, Q and A signals I', Q' and A', respectively, from baseband. This can eliminate the need for a limiter to inject the signals into the phase locked loop of an rTheta architecture. The amplitude signal A' may be generated numerically from baseband such that an envelope detector may not be needed for the analog reconstruction of that signal. Amplitude direct from baseband also can allow flexible phase shifting between amplitude and phase waveforms for rTheta architectures.

More particularly, conventional modulating systems, for example as illustrated in FIGS. **1**, **2** and **3**, generate amplitude information from the IQ signal so that the rest of the transmitter chain may need to be linear enough to meet desired modulation specifications. In contrast, if the amplifiers can be saturated instead of linear, current consumption may be reduced. Moreover, conventional modulation systems may have low levels of linearity for a given current consumption. This may be especially true for modulation schemes whose peak-to-average is not a fundamental limit and even further back-off may be needed to satisfy near channel interference levels.

Moreover, embodiments of FIG. **9** may produce an amplitude control signal **442** that may not be ideal because of distortion caused in the IQ modulator **420**. The amplitude tracking circuit **440'''** also may cause distortion. It also may be generally desirable to place a limiter **1120** between the IQ modulator **420** and the phase locked loop to remove unwanted amplitude information. The limiter **1120** may cause AM/PM distortion in the phase signal **432***a*, **432***b* and also can cause unwanted delay between the amplitude and phase signals when they are combined at the driver stages **1150***a* and **1150***b*.

In contrast, embodiments of FIGS. **10** and **11** can calculate a desired output for an amplitude tracking subsystem **440** (FIG. **4**) and can apply this output directly. Moreover, a limiter may not be needed because limiting may already be incorporated into the generation of the I' and Q' signals.

FIG. **12** is a block diagram of modulating systems and methods according to other embodiments of the present invention. As shown in FIG. **12**, a DSP **920'** generates an I' signal **922'**, a Q' signal **924'** and an A' signal **926'** from a baseband signal **912**. A controlled oscillator **910** and the I' and Q' signals **922'** and **924'**, respectively, are applied to an IQ modulator **930** to produce a modulated signal **932** that is applied to a phase frequency detector or phase detector **940** including a pair of low pass filters **944***a*, **944***b* and a pair of controlled oscillators **942***a*, **942***b*. Also applied to the phase frequency detector **940** is a main local oscillator **990** modulated by second modulators **992***a*, **992***b*. The output of the controlled oscillators **942***a*, **942***b* are applied to amplifiers **950***a* and **950***b*, respectively, which can be variable gain amplifiers and/or other conventional amplifiers such as power amplifiers or driver amplifiers. As also shown in FIG. **12**, amplitude control also may be combined with a power control signal **982** in a combined power control and amplitude control module **980**. Accordingly, an improved rTheta architecture may be provided. FIG. **13** is a block diagram of a single band version of FIG. **12**.

The following equations show how the I', Q' and A' signals may be calculated for embodiments of FIGS. **11**, **12** and **13**:

$$\theta = \tan^{-1}\left(\frac{Q}{I}\right)$$

The angle should be a four-quadrant representation of the I and Q-data.

$$I' = \cos\theta$$

$$Q' = \sin\theta$$

The I' and Q' signals also may be interchanged. Therefore, the I' and Q' signals can be used to modulate the IF, and can create an IF that can be identical to an IQ modulated IF signal that has passed through an ideal limiter. Since the I' and Q' signals can be free of amplitude information, a limiter may not be needed at the input of the phase-frequency detector of the phase locked loop. Phase distortion, or AM/PM distortion that may occur in a real limiter, also may be reduced or eliminated.

The A' signal is calculated as follows:

$$A' = \sqrt{I^2 + Q^2}$$

Since the A' signal is calculated mathematically and applied directly to the amplifier, it need not contain any of the distortion created in the IQ modulation of the IF, and it also need not contain any distortion from the amplitude detector circuit.

Accordingly, limiters/envelope detectors may be removed and related AM/PM distortion may be reduced or eliminated. VCO pulling also may be removed that may arise from amplitude variations on a phase only signal. Sending the amplitude directly from baseband can result in exact and repeatable power control, as well as flexibility in phase shifting of amplitude relative to phase only signals in rTheta transmitters.

Embodiments of the invention that were described in FIGS. **4**–**13** placed the quadrature modulator prior to the phase locked loop. Thus, for example, in FIGS. **4**–**8**, the IQ modulator **420** modulates in-phase and quadrature phase signals, and provides a modulated signal **422** to a phase locked loop in a phase tracking system **430** or **430'**. Similarly, in FIGS. **10**–**11**, the IQ modulator **930** modulates I and Q signals and provides the modulated signal **932** to a phase locked loop **940**. Thus, in these embodiments, the IQ modulation may take place at the IF frequency by directly modulating the IF reference signal.

According to other embodiments that will be described below in connection with FIGS. **14**–**22**, modulation is applied within the phase locked loop itself. In particular, the phase locked loop includes a controlled oscillator having a controlled oscillator input and a controlled oscillator output, and a feedback loop between the controlled oscillator input and the controlled oscillator output. The feedback loop includes a mixer that is responsive to a local oscillator. In some embodiments, the modulator is placed in the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input. Accordingly, the modulation can be applied by modulating a local oscillator signal and leaving the IF as an unmodulated signal. Alternatively, the modulation can be applied to the RF output, and then mixed with an unmodulated local oscillator and IF frequency. In yet another alternative, the modulation may be performed after the mixer in the feedback path of the phase locked loop if it is desired to keep the IQ modulator running at the IF frequency.

For example, FIG. **14** is similar to FIG. **4**, except that the IQ modulator **420** is included within the phase tracking subsystem **430"**, preferably within the feedback loop of the phase locked loop of the phase tracking subsystem **430"**. FIG. **15** is similar to FIG. **10**, except the IQ modulator **930** is included within the phase locked loop **940'**, preferably within the feedback loop thereof.

FIG. **16** is a block diagram of embodiments of the invention that illustrate various alternative locations of the IQ modulator within the phase locked loop. It will be understood that FIG. **16** can correspond to the phase tracking system **430** of FIG. **4**, **430'** of FIGS. **5**–**8** and/or **430"** of FIG. **14**, and/or the phase locked loop **940** of FIGS. **10**–**13**, and/or **940'** of FIG. **15**.

As shown in FIG. **16**, the phase locked loop **1600** includes a phase detector or phase-frequency detector **1620** that can correspond to the phase-frequency detector or phase detector **537** of FIGS. **5**–**8**, **1140** of FIG. **9** and/or **940** of FIGS. **12**–**13**, and a low pass filter **1630** that can correspond to the low pass filter **538**f FIGS. **5**–**8**, **1144***a* of FIG. **9**, and/or **944***a* of FIG. **12**. A controlled oscillator, such as a Voltage Controlled Oscillator (VCO) **1640** can correspond to the VCO **532** of FIGS. **5**–**8**, **1142***a*, **1142***b* of FIG. **9**, **942***a*, **942***b* of FIG. **12** and/or **942** of FIGS. **10**, **11**, **13** and **15**. As also shown in FIG. **16**, the controlled oscillator has a controlled oscillator input **1604** and a controlled oscillator output **1606**. A feedback loop **1602** is provided between the controlled oscillator output **1606** and the controlled oscillator input **1604** via the phase-frequency detector or phase detector **1620** and low pass filter **1630**. The feedback loop includes a mixer **1660** that can correspond to the mixer **533** of FIGS. **5**–**8**, **533***a*, **533***b* of FIG. **9**, **922***a*, **922***b* of FIG. **12** and/or **922** of FIG. **13**, and a local oscillator **1680** that can correspond to the local oscillator **534** of FIGS. **5**–**9** and/or **990** of FIGS. **12**–**13**.

In FIG. **16**, four possible locations of the IQ modulator corresponding to IQ modulator **420** of FIGS. **4**–**9** and/or **930** of FIGS. **10**–**13** are shown by IQ modulators **1610**, **1650**, **1670** and **1690**. It will be understood by those having skill in the art that only one IQ modulator need be provided at only one of the positions shown in FIG. **16**. However, multiple IQ modulators also may be provided.

The IQ modulator **1610** is placed prior to the phase locked loop **1600** in a manner corresponding to FIGS. **4**–**13** as was described extensively above. The IQ modulator **1650** is placed in the feedback loop **1602** between the controlled oscillator output **1606** and the mixer **1660**. The IQ modulator **1670** is placed in the feedback loop **1602** between the local oscillator **1680** and the mixer **1660**. Finally, the IQ modulator **1690** is placed in the feedback loop **1602** between the mixer **1660** and the controlled oscillator input **1604**.

When the IQ modulator **1650** is placed between the output of the controlled oscillator **1606** and the mixer **1660**, the RF output signal of the controlled oscillator **1640** is modulated with the I and Q signals. Thus, this is an example of RF modulation. When the IQ modulator **1690** is placed between the mixer **1660** and the controlled oscillator input **1604**, this can correspond to IQ modulating at the IF frequency, but the modulation takes place in the feedback loop **1602** of the phase locked loop **1600**, rather than at the IF input, as would be the case with modulator **1610**. When the modulator **1670** is placed between the local oscillator **1680** and the mixer **1660**, the local oscillator frequency is modulated before it is mixed with the RF to create the IF feedback signal. The phase can be preserved through the mixer, so that an analogous situation to modulating with modulator **1610** may be provided.

It will be understood by those having skill in the art that each of the four positions of the modulators **1610**, **1650**, **1670** and **1690** shown in FIG. **16** can provide the same result at the output. Various considerations may be used in deciding where to place the modulator. For example, it may be more efficient to IQ modulate at the IF frequency, so that modulators **1610** and **1690** may be preferred. Modulating at RF (modulator **1650**) or at the local oscillator (modulator **1670**) may consume more current than modulating at IF. However, the current consumption may depend on the frequency plan of the system. It also will be understood that an amplitude signal may be generated and/or applied in a manner that was described in any of the previous figures.

FIG. **17** is a block diagram that is similar to FIG. **5**, except the IQ modulator **1650** is placed in the feedback loop between the output of the controlled oscillator **532** and the mixer **533**, rather than the IQ modulator **420** of FIG. **5**. An IQ modulator **1670** or **1690** of FIG. **16** also may be used in embodiments of FIG. **17**.

FIG. **18** illustrates the use of an IQ modulator **1670** between the local oscillator **534** and the mixer **533**, instead of the IQ modulator **420** at the input of the phase locked loop in FIG. **6**. It will also be understood that an IQ modulator **1650** or **1690** of FIG. **16** also may be employed.

FIG. **19** illustrates the use of an IQ modulator **1690** between the mixer **533** and the input of the controlled oscillator **532**, instead of the IQ modulator **420** of FIG. **7**. It also will be understood that IQ modulators **1650** or **1670** also may be used. IQ modulators also may be used in the positions shown in FIG. **16** in other embodiments of the invention according to FIGS. **8** and **9**.

FIG. **20** illustrates the use of a modulator **1650** between the output of the controlled oscillator **942** and the mixer **992**, instead of the IQ modulator **930** of FIG. **13**. FIG. **21** illustrates an IQ modulator **1670** between the local oscillator **990** and the mixer **992**, instead of the IQ modulator **930** of FIG. **13**. FIG. **22** illustrates an IQ modulator **1690** between the mixer **992** and the input of the controlled oscillator **942**, instead of the IQ modulator **930** of FIG. **13**. Similar placements of the modulator may be provided for the embodiments of FIG. **12**.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

What is claimed is:

1. A modulation system comprising:

a quadrature modulator that modulates in-phase and quadrature-phase signals to produce a modulated signal;

a phase tracking subsystem that is responsive to the quadrature modulator to produce a phase signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal;

an amplitude tracking subsystem that is responsive to the quadrature modulator to produce an amplitude signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal; and

an amplifier having a signal input, an amplitude control input and an output, wherein the signal input is responsive to the phase signal and the amplitude control input is responsive to the amplitude signal;

wherein the phase tracking subsystem comprises a phase locked loop that includes a controlled oscillator having a controlled oscillator input, a controlled oscillator output that produces the phase signal and a feedback loop between the controlled oscillator input and the controlled oscillator output, the feedback loop including a mixer that is responsive to a local oscillator, and wherein the quadrature modulator is included within the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input.

2. A system according to claim **1** wherein the amplitude tracking subsystem comprises an automatic gain control subsystem that is responsive to the modulated signal to produce the amplitude signal.

3. A system according to claim **1** wherein the phase tracking system further comprises a limiter between the quadrature modulator and the phase locked loop.

4. A system according to claim **1** further comprising:

a power amplifier that is responsive to the output of the amplifier having a signal input, an amplitude control input and an output; and a transmit antenna that is responsive to the power amplifier.

5. A system according to claim **1** further comprising a transmit antenna that is responsive to the output of the amplifier and a user interface that generates the in-phase and quadrature signals in response to user input, to provide a wireless communications terminal.

6. A system according to claim **1** wherein the amplifier is a power amplifier.

7. A modulation system comprising:

a quadrature modulator that modulates in-phase and quadrature-phase signals to produce a modulated signal;

a phase tracking subsystem that is responsive to the quadrature modulator to produce a phase signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal;

an amplitude tracking subsystem that is responsive to the quadrature modulator to produce an amplitude signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal, wherein the amplitude tracking subsystem comprises an automatic gain control subsystem that is responsive to the modulated signal to produce the amplitude signal;

an amplifier having a signal input, an amplitude control input and an output, wherein the signal input is responsive to the phase signal and the amplitude control input is responsive to the amplitude signal;

wherein the phase tracking subsystem comprises a phase locked loop that includes a controlled oscillator having a controlled oscillator output that produces the phase signal and wherein the quadrature modulator is included within the phase locked loop; and

wherein the automatic gain control subsystem further comprises:

a first envelope detector that is responsive to the modulated signal;

a second envelope detector that is responsive to the phase locked loop; and

a comparator that is responsive to the first and second envelope detectors to produce the amplitude signal.

8. A modulation system comprising:

a quadrature modulator that modulates in-phase and quadrature-phase signals to produce a modulated signal;

a phase tracking subsystem that is responsive to the quadrature modulator to produce a phase signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal;

an amplitude tracking subsystem that is responsive to the quadrature modulator to produce an amplitude signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal, wherein the amplitude tracking subsystem comprises an automatic gain control subsystem that is responsive to the modulated signal to produce the amplitude signal;

an amplifier having a signal input, an amplitude control input and an output, wherein the signal input is responsive to the phase signal and the amplitude control input is responsive to the amplitude signal;

wherein the phase tracking subsystem comprises a phase locked loop that includes a controlled oscillator having a controlled oscillator output that produces the phase signal and wherein the quadrature modulator is included within the phase locked loop

wherein the automatic gain control subsystem further comprises:

a first envelope detector that is responsive to the modulated signal;

a second envelope detector that is responsive to the amplifier; and

a comparator that is responsive to the first and second envelope detectors to produce the amplitude signal.

9. A modulation system comprising:

a quadrature modulator that modulates in-phase and quadrature-phase signals to produce a modulated signal;

a phase tracking subsystem that is responsive to the quadrature modulator to produce a phase signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal;

an amplitude tracking subsystem that is responsive to the quadrature modulator to produce an amplitude signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal;

an amplifier having a signal input, an amplitude control input and an output, wherein the signal input is responsive to the phase signal and the amplitude control input is responsive to the amplitude signal;

wherein the phase tracking subsystem comprises a phase locked loop that includes a controlled oscillator having a controlled oscillator output that produces the phase signal and wherein the quadrature modulator is included within the phase locked loop; and

wherein the amplitude tracking subsystem further comprises an envelope detector that is responsive to the modulated signal to produce the amplitude signal.

10. A modulation method comprising:

modulating in-phase and quadrature signals to produce a modulated signal;

producing a phase signal from the modulated signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal using a phase locked loop that includes a controlled oscillator having a controlled oscillator input, a controlled oscillator output and a feedback loop between the controlled oscillator input and the controlled oscillator output, the feedback loop including a mixer that is responsive to a local oscillator, wherein the modulating is performed in the feedback loop between the controlled oscillator output and the mixer, between the local oscillator and the mixer, or between the mixer and the controlled oscillator input;

producing an amplitude signal from the modulated signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal; and

amplifying the phase signal at a gain that is varied in response to the amplitude signal.

11. A method according to claim **10** wherein the producing an amplitude signal from the modulated signal comprises automatic gain controlling the modulated signal to produce the amplitude signal.

12. A method according to claim **10** further comprising limiting the modulated signal, and wherein the applying the modulated signal to a phase locked loop comprises applying the limited modulated signal to a phase locked loop that includes a controlled oscillator having a controlled oscillator output that produces the phase signal.

13. A method according to claim **10** further comprising: transmitting the amplified phase signal.

14. A method according to claim **13** further comprising: generating the in-phase and quadrature signals in response to user input, to provide a wireless communications method.

15. A modulation method comprising:

modulating in-phase and quadrature signals to produce a modulated signal;

producing a phase signal from the modulated signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal using a phase locked loop that includes a controlled oscillator having a controlled oscillator output, wherein the modulating is performed within the phase locked loop;

producing an amplitude signal from the modulated signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal;

amplifying the phase signal at a gain that is varied in response to the amplitude signal;

wherein the producing an amplitude signal from the modulated signal comprises automatic gain controlling the modulated signal to produce the amplitude signal; and

wherein the automatic gain controlling comprises:

envelope detecting the modulated signal;

envelope detecting a signal in the phase locked loop; and

comparing the envelope detected modulated signal and the envelope detected signal in the phase locked loop to produce the amplitude signal.

16. A modulation method comprising:

modulating in-phase and quadrature signals to produce a modulated signal;

producing a phase signal from the modulated signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal using a phase locked loop that includes a controlled oscillator having a controlled oscillator output, wherein the modulating is performed within the phase locked loop;

producing an amplitude signal from the modulated signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal;

amplifying the phase signal at a gain that is varied in response to the amplitude signal;

wherein the producing an amplitude signal from the modulated signal comprises automatic gain controlling the modulated signal to produce the amplitude signal; and

wherein the automatic gain controlling comprises:

envelope detecting the modulated signal;

envelope detecting the amplified phase signal; and

comparing the envelope detected modulated signal and the envelope detected amplified phase signal to produce the amplitude signal.

17. A modulation method comprising:

modulating in-phase and quadrature signals to produce a modulated signal;

producing a phase signal from the modulated signal that is responsive to phase changes in the modulated signal and that is independent of amplitude changes in the modulated signal using a phase locked loop that includes a controlled oscillator having a controlled oscillator output, wherein the modulating is performed within the phase locked loop;

producing an amplitude signal from the modulated signal that is responsive to amplitude changes in the modulated signal and that is independent of phase changes in the modulated signal;

amplifying the phase signal at a gain that is varied in response to the amplitude signal; and

wherein the producing an amplitude signal from the modulated signal comprises:

envelope detecting the modulated signal to produce the amplitude signal.

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